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PHYSIOLOGICAL FACTORS IN MINE VENTILATION IN 1931

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PHYSIOLOGICAL FACTORS IN MINE VENTILATION IN 1931[1]

By R. R. Sayers[2]

The hazards connected with work under abnormal air conditions are becoming of increasing importance from a financial as well as a physiological standpoint, due to the extension of compensation laws to include diseases caused by dusts, toxic gases, and abnormal temperatures and humidities.

The United States, with the exception of California, North Dakota, Wisconsin, Massachusetts, and Connecticut, is the only English-speaking country to-day where silicosis is not compensated.[3] Cases of permanent total disability or death due to silicosis may appear in common-law courts, particularly in the States that have not recognized silicosis as an occupational disease for which compensation should be provided. Such cases have recently been tried in one State,[4] according to a magazine editorial, not providing scheduled compensation for employees affected by silicosis, with results favorable to the claimant. Clearly established cases definitely linked with occupation as the cause may be expected to be recognized as deserving by juries and courts, and awards will be made. In one Atlantic Coast State, according to this editorial, 108 claims for silicosis, including 21 deaths therefrom, are said to have been filed against two small plants engaged in finely pulverizing quartz sand.

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6645."
Report of the Chairman of the Subcommittee on Physiological Factors of the Committee on Ventilation of the American Institute of Mining and Metallurgical Engineers, presented at the meeting in New York City, February, 1932.

[2] - Chief surgeon, or chief, health and safety branch, U. S. Bureau of Mines; surgeon, U. S. Public Health Service.

[3] - Hayhurst, E. R., Compensation for Silicosis: Jour. Am. Med. Assoc., vol. 97, No. 9, August 29, 1931, pp. 660-661.

[4] - Industrial and Engineering Chemistry, Beware of Silicosis! Editorial, vol. 23, No. 10, October, 1931, pp. 1082-1083.

Under the New York compensation act, compensation claims in nine cases of carbon monoxide poisoning were granted and three disallowed during 1931, according to report of the New York State Department of Labor.[5]

The death of a workman from the inhalation of carbon monoxide in the course of his employment in a mine was, in the opinion of the court of appeals of Ohio,[6] due to an "accidental injury" within the meaning of the Ohio compensation act, and not to an occupational disease.

A review of the literature published since the last report of the effects on workers of injurious dusts, gases, and variations in temperature and humidity indicates the importance of such hazards from the physiological standpoint.

SUMMARY OF RECENT LITERATURE CONCERNING EFFECTS ON WORKERS OF EXPOSURE TO DUSTS

Dusts may be either poisonous--as lead, arsenic, and zinc--or nonpoisonous --as coal, silica, quartz, limestone, talc, asbestos, and dusts from similar substances. From the standpoint of health, with the possible exception of lead dusts, the most important dusts are those causing various types of pneumoconiosis, although all dusts may be injurious if breathed in sufficient quantities for a long enough time. Investigations in the various countries during the past year were concerned mostly with silicosis, as indicated by the literature on dust diseases.

Australia.- In order to determine the incidence of fibrous pneumoconiosis among coal miners before rock-dusting had been in practice for any length of time, 471 volunteers from among miners with at least 10 years underground experience were examined by the Division of Inudstrial Hygiene of the New South Wales Government.[7] Of the men examined, 199 came from one mine, among the employees of which a number of cases of pulmonary fibrosis had occurred; the remaining 277 volunteers were employed in eight other mines of the district.

The miners were divided into four classes:

A. Men who had mined in coal only and in only one pit, in which they were working at the time of examination.
B. Men who had mined in coal only and only on the South Coast of New South Wales.
C. Men who had mined in coal only, but in other districts in Australia and elsewhere as well as the South Coast district.
D. Men who had worked in metal mines, quarries, etc., as well as in coal mines.

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[5] - New York State Department of Labor, Industrial Hygiene Bulletin: Vol. 7, No. 11, May, 1931, pp. 41-42.

[6] - Journal of the American Medical Association, Medicolegal, Workmen's Compensation Acts: Compensability of Carbon Monoxide Poisoning: Vol. 97, No. 26, De 26, 1931, p. 1986.

[7] - Moore, Keith R., Fibrosis of the Lungs in South Coast Coal Miners, New South Wales: Health, Commonwealth Department of Health, vol. 9, No. 5, May, 1931, 10 pp.

The men were classified according to length of mine experience and the percentages of men in each group who showed radiographic evidence of fibrosis, simple or complicated. No one in the group of men with 10 years or less experience showed evidence of fibrosis. The percentage of cases of fibrosis increased with length of exposure until the figure of 40.8 was shown for the group of men with over 30 years industrial history. The percentage for all man examined was 25.9.

The percentages of fibrosis among men with a coal-mining history only were fairly constant for the three classes A, B, and C, ranging from 22.5 to 25.7 per cent. The incidence in group D, men who had also done other classes of mining, was high--39.7--but this was accounted for, partly at least, by the increased proportion of older men in this group.

The percentage of fibrosis in men who had worked only on the South Coast was higher than in men who had mined coal in the South Coast and elsewhere in Australia or overseas, the average for classes A and B being 25.0 as against 22.5 per cent for class C.

The dust to which coal miners in class A had been exposed is that originating from the cutting of coal seams about 6 feet thick. The coal contains about 13 per cent of ash and not more than 2 per cent of free silica. The country rock is shale. In one mine the extraction of pillars caused very dusty conditions. A detailed investigation into the nature, size-frequency, and concentration of dust inhaled by coal miners has not yet been carried out.

In order to correlate the radiological with the clinical findings, 32 coal miners with varying degrees of fibrosis were examined clinically. The examinations revealed comparative freedom from symptoms and lack of gross physical signs in cases which showed apparent serious involvement radiographically.

The symptom most commonly complained of was shortness of breath (24 men), and the most frequently found sign was that of deficient air entry (12 men). Rhonchi were found in 10 men, one of whom was under treatment for bronchial asthma, and another for chronic bronchitis, while a third was drawing a military pension for "chest trouble." In two men only was there a history of the occasional appearance of streaks of blood in the sputum, and in both of these the radiographic diagnosis was simple fibrosis. They complained of sweating at night. Two others complained of pains in the chest.

A fine type of fibrosis of the lungs varying in degree from slight to marked was found to be present in 122 of 471 (25.9 per cent) coal miners examined, and the incidence among men who had worked on the South Coast coal field only was 25.0 per cent. This radiographic fibrosis was considered to be complicated by infectious processes in 49 of the 122 cases. Radiographic appearances of tuberculosis in the form of an acute lesion, a latent process, or an old scar were found in 24 or 5.1 per cent of the 471 men examined. The investigators reached the following general conclusions:

While it is evident from the radiographic findings that a pulmonary fibrosis may be produced by work in coal mines on the South Coast, it also seems that this fibrosis is of slower onset and the resulting disability less marked than in the fibrosis found in metal miners and workers exposed to dust with a high free silica content.

From the statements made above and the clinical examination of 32 men, the conclusion is drawn that the diagnosis of pulmonary conditions in these miners and the estimation of their disability must depend less on the radiographic findings than on the results of clinical examination.

Among the coal miners examined and still at work there is a higher incidence of simple and of complicated fibrosis according to radiographic evidence than among the metalliferous miners of Broken Hill and Tasmania, but a lower incidence than was found in metalliferous miners in Western Australia[8]; however, as the prognosis of the fibrosis of these coal miners is not known, this comparison is at present of no value.

Recent advances in radiological technique probably account in some measure for the definite X-ray appearance of slight to marked fibrosis in these cases. It is considered unlikely that all cases showing evidence of a complicated fibrosis are tuberculous, and even if tuberculous infection has been associated with these cases, it is active in very few.

It is highly important that this condition of fibrosis among coal miners should be placed on a sound pathological and chemical basis, and that every opportunity should be taken to study the pathology and histology of affected lungs to correlate the conditions found with radiographs taken before death, and to have full chemical analyses made.

To gain further knowledge of the cause of this form of fibrosis of the lungs it will be necessary to conduct inhalation experiments with animals.

According to the Queensland Government Mining Journal,[9] in a review of the position as regards lead absorption and lead intoxication at Mount Isa up to October 17, 1931, lead poisoning was found to occur among workers mining the ore in the carbonate stopes, tranporting the same on the haulage levels, and smelting the concentrates after treatment in the mill. Mild poisoning which responded rapidly to treatment was found in only three of the 145 underground workers examined. In the smelting section, 48 men of the approximately 260 examined manifested symptoms of lead intoxication, mild and transient in the majority of cases and of varying severity in a few. In a number of cases recurrences of the symptoms have been noted after return

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8 - Nelson, W. T., Report on an Investigation of the Pulmonary Conditions of Mine Employees, Western Australia, During the Years 1925-1926: Service Publication (Division of Industrial Hygiene) No. 5, Commonwealth Department of Health, Canberra, Australia.

9 - Queensland Government Mining Journal, Lead Poison Dangers, Mount Isa; Safeguarding Workers: November, 1931, p. 447.

to work. The longest period of acute disability under treatment was about four days in three cases. The treatment used is a removal of the poisoned worker from all chance of further ingestion, the allaying of acute symptoms by appropriate drugs, and the elimination of lead from the system after the acute stage has passed. The main objective is prevention by the installation of suitable exhausts and other dust-eliminating devices where the lead hazard is severe; provision and routine use by the men of respirator masks; ample and convenient water supplies for washing and drinking purposes, with an up-to-date change house under efficient supervision; provision of medicine, readily obtainable by the men; routine examination of the workers at regular intervals; and hospital treatment of poisoned workers, or in milder cases suitable out-patient treatment and observation.

According to the report there is a definite decrease in the incidence of lead poisoning, due primarily to the increased efficiency in lead-dust disposal, combined with the cooperation of the workers in better personal hygiene and in the early seeking of medical advice when in doubt about their health. All the workers now recognize the danger associated with the industry, the existence of which was unknown to the majority in the beginning.

In an anonymous article in the Engineering and Mining Journal[10] the statement is made that, although silicosis is inherently most difficult to combat, and will remain so while mineral-bearing material has to be drilled, blasted, and removed in confined spaces, plumbism, because it becomes manifest within a comparatively short period and has well-defined and easily recognized signs and symptoms, can be placed under control without loss of plant efficiency. As a matter of fact, if the remarkable result achieved at Port Pirie, Australia, be any criterion, then according to this article full success in the elimination of plumbism will give greatly increased technical efficiency. Since 1925, the problem of reducing the incidence of plumbism among employees of the Broken Hill Associated Smelters, at Port Pirie, has been continuously and thoroughly investigated. The plan of campaign has been to study the working conditions at each locality where a man who has contracted plumbism has been at work and to decide forthwith the alterations necessary to effect improvement. In many instances, these alterations have been simple and inexpensive, whereas in others a huge expenditure has been called for, particularly so when the improvement was primarily designed to advance metallurgical technic. This plan, administered by an industrial health department, has given success beyond all expectations. For the half year ended December, 1925, complete Government records show that 131 cases of plumbism prevailed among 2,615 employees, whereas for the corresponding period five years later, only eight cases prevailed among 1,500. Concurrently with the decrease in the number of cases, a diminution in the severity or period of disability of plumbism cases has taken place. Complete statistics are not available, but those that are available show that the average period of disability in 1929-30 amounted to only one-half that in 1927-28 and less than one-third that in 1926-27. For the half year ended January 14, 1931, the period of disability averaged 11 weeks, with a maximum of 15 weeks. The decrease in the period and in the incidence of plumbism among short-service employees makes evident the fact that the unhealthful working places, where employees were exposed to highly concentrated dust and fume, have been eliminated.

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[10] - Engineering and Mining Journal, Lead Poisoning Checked in Australia: December 14, 1931, pp. 488-490.

In summarizing, the article states that in stamping out a persistent health hazard within five years, the Broken Hill Associated Smelters, which to-day has an annual output of 175,000 tons of lead and 270 tons of silver, has made a remarkable achievement in industrial hygiene. Experience at Port Pirie has shown that in lead smelting the prevalence of dust and fume in and around localities where operatives are at work is certain to give rise to plumbism. Given adequate prevention and collection appliances for dust and fume, no man-handling of sinter and furnace charges and drosses, no dusty roads, no poorly operating smelting furnaces, and ample washing facilities, plumbism as a health hazard will not exist.

Austria.- Examination was made of 40 workers in an iron foundry in Vienna; 28 were moulders, 9 helpers, and 3 cleaners of castings; all had worked for more than 10 years. Four cases of pronounced and five of slight pneumoconiosis were found; three cases were doubtful. The author[11] compares the 7.8 per cent he found with the incidence of 5 per cent among porcelain workers and 28 per cent among coal miners having more than 10 years employment. The investigation indicated the necessity of improving hygienic conditions and careful attention to ventilation.

Canada.- Of 38 men engaged in the founding of bronze who were sent to the hospital for various complaints, 24 were found to be suffering from acute lead poisoning; 9 showed definite evidence of lead absorption; and only 5 showed no signs of plumbism. Bronzes of the type in question may contain up to 20 per cent of lead.

Blood smears of 26 men engaged in the polishing of low-lead brass and bronze (less than 6 per cent) showed that five had stippled cells, well in excess of 200 per million red cells.

The air in one foundry was found on analysis to contain a concentration of lead of about 0.85 milligram per cubic meter.[12]

England.- Captain Hay,[13] in a lecture entitled "Dust Prevention in Iron Ore Mines," did not discuss the health aspect but said that the following factors must be borne in mind in prevention of the dust hazard: The concentration of the dust in the atmosphere being breathed; the length of time of

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11 - Komissaruk, B., Pneumokoniose, Tuberkulose and soziale Verhältnisse bei Eisengiessern in Wien: Arch. f. Gewerbepath. u. Gewerbehyg, vol. 2, Berlin, 1931, pp. 123-39. Abstracted by Bull. Hygiene, London, vol. 6, No. 12, Dec., 1931, pp. 860-861.

12 - Pedley, F. G., and Ward, R. V., Lead Poisoning in Brass and Bronze Foundries: The Canadian Med. Assoc. Jour., vol. 25, No. 3, Sept. 1931, pp. 299-303.

13 - The Colliery Guardian, Dust Prevention in Mines: July 31, 1931, pp. 371-72.

exposure to that dust; and the size of the dust particles. He said that the risk from iron-dust was negligible as compared with the dust containing a large proportion of free silica.

Cummins[14] in a paper on coal miners and tuberculosis considers the question of how it happens that coal miners, a class now recognized as sufficiently exposed to injurious dusts to develop a fairly high percentage of silicosis, and a class exhibiting a high death rate from other respiratory diseases, are notorious for their low death rate from tuberculosis.

After reviewing some of the literature on the subject, he makes the following statement:

> Recent observations by the writer and Dr. Weatherall have proved that coal-dust in fine division can adsorb and inactivate tuberculin solutions to a marked extent; and the writer tends more and more to the view that it is in this direction that the relative exemption of coal miners from tuberculosis is to be explained. When it is recalled that the lungs of silicotic and anthracotic coal miners may contain over 100 grams of coal-dust, as shown by Cummins and Sladden in their recent work, it will be readily conceded that the available adsorption potential of carbonaceous matter in silico-anthracotic lung tissues may be very great.
>
> It must not be supposed, however, that the presence of accumulated coal-dust in the lungs is an unmixed blessing. On the contrary, it may have very disagreeable or even dangerous results. While it seems to have a definitely beneficial effect in lessening the liability to the extension of tuberculous lesions it may, by its mere accumulation, come to occupy large areas of lung tissues to an extent which leads not only to fibrosis and devascularization, but sometimes to colliquative changes and even cavity formation. With these changes there is brought about, to a gradually increasing extent, a state of lung emphysema accompanied by structural deterioration of alveolar tissue, bronchioles and even bronchi which involves serious interference with the function of respiration.
>
> Most old coal miners are dyspnoeic. Although many of them work on to a great age, they are, as a rule, "short of breath" and suffer from copious sputum, cough and sometimes asthmatic trouble.
>
> While the collier is fortunate in having a relatively low death rate from tuberculosis, his death rate from "bronchitis" is very high.
>
> Whether the word "bronchitis" is well chosen to describe the dyspnoeic state in which old coal miners so commonly die is open to question; and it is a question, too, whether they merely die dyspnoeic or die from dyspnoea. Certain it is that the effects of stone-dust and

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[14] - Journal of State Medicine, London, Coal Miners and Tuberculosis (A Paper read at the Frankfurt Congress): Vol. 39, No. 9, Sept., 1931, pp. 526-36.

coal-dust combined tend, after a life spent in the industry, to produce a state in which the breathing efficiency of the lungs is seriously compromised.

Haldane lays stress on the hard muscular work involved in coal-getting as an important factor in the production of chronic bronchitis and emphysema. It would be rash to minimize the possibilities of hard muscular work as a cause of emphysema. The histological and pathological examination, however, of the lungs of coal miners dying at different ages and stages of industrial exposure to mixed coal and stone dusts shows tha quite apart from any possible effect of inordinate muscular effort, there exists a condition of pneumonoconiosis which is in itself sufficient to account for the dyspnoea and bronchitis from which old coal miners suffer

The fact that the apex of the curve of "bronchitis" mortality in coal miners occurs so late in life shows that the state of lung injury above described is often consistent with survival to a ripe old age. It does, however, involve marked respiratory distress and considerable loss of health. This pneumonoconiosis of coal miners is at least a contributory cause in many of the deaths attributed to 'bronchitis' and it appears in itself, to lead to a fatal issue in some cases. The attitude of complacency commonly assumed toward the risks run by coal miners from exposure to the mixed dusts of the coal mines is obviously unjustifiable.

Coal mining involves a definite risk of pneumonoconiosis. While it is true that the silicosis which the collier develops is not usually associated with increased liability to tuberculosis, it does lead to a marked and potentially injurious accumulation of coal dust in the lungs. Everything possible should be done to minimize this risk. Two valuable lines of prophylaxis are open to further investigation. On the one hand there is the closer study of the constituents of the stone-dusts used to diminish the danger of explosions. Much more accurate knowledge is needed as to what percentage of silica may be regarded as safe in this connection. The value of stone-dusting needs no emphasis. It must continue. But the selection of the stone used for the production of the dust is clearly a matter of the greatest importance and further research as to limits of safety in each of the constituents of such stone-dust is urgently required.

Ellman[15] in reporting a case of pulmonary asbestosis stated:

> In my cases the onset of symptoms has usually been about five years after exposure to the dust, beginning with a cough, with little expectoration, and accompanied by dyspnoea, both of which become progressively worse. There is always some wasting, sometimes quite marked, and the physical signs are usually those of a basal fibrosis to begin with, followed by extension of the infiltration upwards, but affecting mainly,

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[15] - Proceedings of the Royal Society of Medicine, Pulmonary Asbestosis: Vol. 24, No. 5, March, 1931, pp. 526-28.

as in Dr. B. Wood's cases, the lower and middle zones. The heart and mediastinum are drawn over to that side where the degree of fibrosis is most marked. The adventitious sounds are of a dry, crackling nature, and are probably due, to a large extent, to friction from the accompanying pleurisy.

In the case now shown there is a suspicion of an annular shadow in the left infraclavicular region, suggestive of a cavity. The asbestos fibres have strong penetrating qualities, and commonly penetrate the skin of workers, producing asbestos "corns." Gloyne has shown that asbestos fibres can be removed from the corns with a fine needle. The characteristic golden yellow asbestos bodies may be found in the skin, sputum and lung. The prognosis, when the disease is established, is, on the whole, bad. Tuberculosis is not usually a terminal condition as it is in silicosis. Many patients die from an ensuing bronchopneumonia, and post-mortem examination has shown no evidence of tubercle. When there is persistent absence of tubercle bacilli and a history of prolonged exposure to the dust, with signs and symptoms already outlined, a diagnosis of pulmonary asbestosis can be made.

According to Cooke,[16] so far as can be ascertained no case of pulmonary asbestosis has been recorded in a worker in iron-free asbestos such as has occurred in Arizona, Italy, and Finland. The point is of considerable importance in the explanation of several phenomena observed in the chrysotile worker. Specimens of iron-free asbestos do not show the blue, black, or brown particles seen in chrysotile. He describes the action of asbestos as follows:

> Sections of the lungs and the results of digestion of the lung with trypsin show an enormous amount of fine black granular dust. In addition there are two striking features. The first is the almost complete absence of the very fine translucent spicules of fibre which make up the great proportion of dust in factories. This point will be referred to later. The second feature is the presence of large fragments varying in length from 10 to 360 microns. They are found in fibrotic and necrotic areas, singly, and in groups. The particles are so large--masses of them are seen in some sections--that they must have occluded small bronchi and resulted in fibrosis of the surrounding area. Comparing these large particles in the lung with those found in asbestos-dust the close resemblance in sizes, shapes, and colours is apparent. There are the same black, blue, brown, and translucent fragments. In fact it is easy to take each single particle from the lung and immediately find its brother in a slide made from the dust.
>
> In true silicosis, particles of this size are never found, and I have not seen particles approaching these dimensions in any condition except in a case of pneumonoconiosis due to flue-dust. The insoluble siliceous matter in flue-dust contains in addition to quartz grains many acicular crystals and flat plates--transparent

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16 - The Journal of State Medicine, London, Asbestos Dust and Asbestosis Bodies from the Lungs of an Asbestos Worker (A Paper read at the Frankfurt Congress): Vol. 39, No. 9, Sept., 1931, pp. 544-48.

and opaque--of micaceous and felspathic origin. The dust contains 27 per cent of iron as ferric oxide and much of the siliceous matter is colored red from its presence. In sections, and after digestion of the lung in this condition, large particles similar to those found in the asbestos case were found.

Asbestos as a pathogenic agent would appear to act in two ways. The first, as a direct mechanical irritant, is suggested by the large amount of fine granular dust, the larger angular particles, and the presence of much fibrous tissue with multinucleated giant cells not associated with an endothelial and round cell system in sections of the lungs. The presence of acicular crystals can not be ignored as a source of mechanical irritation. The bases of the asbestosis bodies, and these are multitudinous--sharp spicules of asbestos fibre, biotite, and magnetite 20 to 100 microns in length--must have some mechanical action. These bodies are very readily phagocyted and, although some chemical action certainly exists, one can not overlook the mechanical effect of the particles in the production of fibrosis.

Secondly, chrysotile acts as a pathogenic agent because of its soluble constituents. Race states that from commercial asbestos (presumably chrysotile) silica was extracted by a modified Ringer's solution after eight months to the extent of 28 parts per 1,000,000. We have the almost certain proof that some soluble fraction of asbestos plays a part in the formation of the asbestosis bodies, and Race's observations suggest that chemical action must play a not inconsiderable part in the production of the pulmonary fibrosis.

Tylecote[17] describes a case of asbestos-like bodies in the lungs of a coal miner who had never worked with asbestos. The man said that when young he had worked in mines in Alabama. No asbestos is found in Alabama, which is noted for coal and iron. According to the author -

> The main point of interest in the case is the occurrence in the lungs of bodies which somewhat resemble those that have been described in the lungs of asbestos workers. They simulate these in size and general shape, especially in the rounded swellings at the ends; in colour; and in their abundant content of free iron. They differ from the familiar asbestos bodies in being usually coarser and less regular, in possessing a black core of opaque material, and in the absence of any appearance of segmentation. It is presumed that they are minute fragments of some other iron-containing mineral, which have been inhaled into the lungs and undergone some chemical change under the influence of the tissue fluids resulting in the formation of a peripheral lamina from the iron-containing part. They do not appear to have caused a very serious fibrous reaction in the lungs in this case.

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[17] - The Lancet, Case of Asbestos-Like Bodies in the Lungs of a Coal-Miner Who Had Never Worked in Asbestos: Vol. 221, No. 5638, Sept. 19, 1931, pp. 632-33.

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The attention of Parliament[18] was called to an inquest of a young woman who had been employed eight years before at an asbestos factory, the verdict being death due to asbestosis accelerated by tuberculosis. A statement was made that the scheme for the asbestos industry does not apply to persons who were not employed in the industry at the time the scheme was made, and that no compensation, therefore, would be payable in the case.

The Home Secretary was asked[19] for the number of workpeople engaged in the asbestos industry who had been examined by members of the medical board, the number of workpeople found to be suffering from asbestosis, and the number of workpeople suspended from work in the industry by the medical board. The reply was made that 582 workers had been so far examined by the board; three had been found to be suffering from asbestosis, of whom one had been certified as totally disabled and two had been suspended. In addition, one worker had been suspended on account of tuberculosis and one on account of defective physique, making a total of four workers who had been suspended. In 77 of the cases examined the result of a radiological examination was being awaited.

According to the report of the Chief Inspector of Factories and Workshops[20] for 1930, by a recent arrangement the factory-inspection service receives copies of all death certificates in which death resulted from pulmonary disease involving fibrosis of the lungs. Of the 700 such certificates received in 1930, 241 gave silicosis as the cause of death, and in the great majority of cases it was found that the previous occupation of the persons concerned was one in which there was recognized exposure to silica-dust. The industries furnishing the greatest number of such cases were pottery manufacturing; the sandstone industry, industries employing quarrymen and stonemasons; coal mining; gold mining (ex-South African miners); refractories industries; sand blasting; and tin mining.

The report also stated that recent investigations of the effects of exposure to asbestos-dust have resulted in the adoption of measures to control the dust in the textile side of the asbestos industry. Data regarding 20 fatal cases of asbestosis without tuberculosis show that there is a serious hazard involved in continued exposure to heavy concentrations of asbestos-dust. Of the 20 cases, 6 were mattress makers and 6 were carders or cloth weavers, while the remaining cases, it appeared, had been exposed to neighboring dusty processes such as carding and cloth weaving. There is evidence, also, that although removal from exposure to very dusty processes may greatly delay the appearance of a disabling fibrosis or may prevent it entirely if the exposure is not too long, exposure to heavy concentrations of asbestos-dust for a comparatively short period of years will result sooner or later in the

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18 - The Lancet, London, Woman's Death from Asbestosis: Vol. 221, No. 5640, Oct. 3, 1931, p. 775.

19 - The Lancet, London, Asbestosis: Vol. 2, 1932, p. 1385. (Parliamentary Intelligence.)

20 - Industrial Diseases and Poisoning in British Factories, 1930; Silicosis and Asbestosis: Safety Engineering, Dec., 1931, p. 354.

development of a disabling fibrosis. The average age at death of the 20 cases was 38.9 years, and the average length of employment was 14.9 years.

In a brief summary of recent information regarding certain of the pneumoconioses other than silicosis, Collis[21] calls attention to some of the respiratory diseases that may be caused by dust but are seldom recognized as dust diseases. The inorganic dusts he classes as insoluble, soluble and harmful, and mixed. Under the heading of insoluble dusts he mentions that those from certain materials such as basic slag and emery, which is an oxide of aluminum, are insoluble in the tissues. Inhaled particles fall on the walls of the bronchi and bronchioles, where they are entangled in secreted mucus, and then swept back by ciliary action to be expelled finally in sputum. If the dust exposure is sufficient in amount and in time, an inflammatory hyperemia of the walls results, with an excessive exudation of mucus; finally the process extends beyond physiological elasticity; then occur degeneration and destruction of the ciliated mucosa. Microbic invasion follows, and chronic bronchitis is established.

The process described occurs as a reaction to the inhalation of all dusts which are not rapidly absorbed; hence bronchitis stands out as chief of the dust diseases. During middle life it causes much recurrent invalidity and incapacity, and, after middle life is passed, high death rates.

But dust bronchitis can not clinically be distinguished from bronchitis conduced to by exposure at hot furnaces or to fumes in industry, or by severe climatic conditions; hence its association with dust inhalation tends to lack recognition.

Should the dust particles be small enough, 5 microns or less, to be drawn into the finer bronchioles and alveoli, which are the seat of attack for pneumococci, a similar reaction is stimulated; hence the resistance of these parts to infection is lowered, and pneumonia results. Pneumonia is even less recognized as a dust disease than is bronchitis; nevertheless, mortality records of those whose employment subjects them to dust exposure exhibit the fact that death rates from this cause are high.

When, however, fine particles of insoluble dusts are carried on, by phagocyting dust cells, from the alveoli into the lymph stream and lymph nodes of the lungs, they tend to remain there as foreign bodies which do not provoke any particular tissue reaction.

In regard to the soluble and harmful dusts, Collis says that the most studied dust in this group is that of silica. Next come the dusts of silicates; recent work has established that although many silicates, such as fire clay and pottery clays, exert little if any harmful influence upon the lungs, certain other silicates, such as basalt and asbestos, react injuriously with the pulmonary tissues. The reason for these differences is not clear;

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[21] - Collis, E. L., Occupational Dust Diseases: Bull. of Hygiene, vol. 6, No. 9, Sept., 1931, pp. 663-670.

but probably it lies in the constitution of the various silicates, the SiO_2 radical being less firmly attached to the molecule in some cases than in others.

He defines asbestosis as a pneumoconiosis which advances to a fatal end without the supervention of any characteristic infection; it is a simple dust condition, just as is simple silicosis; but it is more distressing in life and more rapid in its progress than is silicosis. It contrasts even more strongly with pulmonary mycosis, which is due to a living infection upon otherwise healthy lungs.

Of the mixed dust he says that so long as any dust consists of one substance only, its influence can be isolated and studied; but the case is different when more than one substance is present in the dust. Coal-dust, which has recently been carefully investigated, is here taken as an instance in point. No undue mortality from respiratory diseases is found among coal miners, so long as the coal worked contains little or no mineral matter--presuming, of course, that the miners are not exposed to other dusts, such as those arising from rocks intervening in the coal measures; of this fact miners on the Nottinghamshire coal field are an example. The lungs of these men may be as black as the coal they work, but they remain resilient and free from fibrosis.

According to Kettle,[22] in Great Britain the dust risks are shared by a number of industries scattered throughout different parts of the country, which makes it difficult to obtain comprehensive morbidity and mortality statistics, but there can be no doubt that industrial pulmonary disease will be of greater importance in social and medical legislation in the near future. He calls attention to the fact that, roughly speaking, the industries in which there is a dust hazard employ twice as many Europeans as the Rand mines and, if the unknown proportion of the huge population of coal miners is included, the question becomes very serious. He also points out that in pulmonary disability, such as miner's phthisis, potter's asthma, grinder's rot, chalicosis, and siderosis, the terminal pathological condition is always the same and the victims die with advanced pulmonary tuberculosis. He therefore considers that pathologists are confronted by two main problems: First, how does silica affect the lung, and how may its action be prevented or modified? And secondly, how does it influence the development of pulmonary tuberculosis?

In regard to the action of silica on the lungs, Kettle mentions that it is now generally accepted that dust inhaled into the terminal alveoli is phagocyted by the pulmonary macrophages and transported to various parts of the lungs, where it presumably gradually becomes dissolved and in the soluble state stimulates the growth of fibrous tissue. He is impressed by the difference in behavior of quartz when it is introduced into the lungs by way of the air passages, and when it is introduced directly into the tissues by subcutaneous inoculation. In the one case it is ingested by phagocytes, which

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[22] - Kettle, E. H., Relation of Dust to Infection: Proc. Roy. Soc. Med., vol. 24, No. 1, London, pp. 79-94. Nov., 1930.

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may remain quiescent in the pulmonary alveoli for long periods without signs of tissue reaction; in the other, necrosis of the tissue takes place within hours or days and there is an active inflammatory reaction. Presumably fibrosis can occur only if silica is brought into direct contact with fibrous tissue or cells capable of forming it. Kettle is of the opinion that the various stages in the development of pulmonary silicosis have not been fully worked out. He doubts the truth of the statistics indicating that workers in certain dusty trades, although exposed to a high percentage of silica, do not suffer from silicosis. He states that whatever may be the explanation of the relative immunity of the coal miner to tuberculosis, if such immunity reall exists, it can not be the absence of silicosis. In his opinion the experiments that have been accepted in the past as having significance are incapable of giving the required answer; there must be a base line to work on--that is, the production of characteristic silicosis in animals--and in the absence of this we are not justified in claiming experimental knowledge of how silicosis may be modified.

In regard to the effect of silica on pulmonary tuberculosis, Kettle[23] says that although silica may itself produce profound changes in the lungs, industries are now so controlled that workers are rarely choked with dust; they inhale a certain amount of silica, which may produce a fairly advanced fibrosis of the lungs, but the chief danger lies in the influence of the dust on microbic infection. He mentions experiments by Gardner as well as by himself which seem to indicate that with silica-dust, although it does not affect the total growth of the tubercle bacillus, the lag period seems to be shortened so that abundant growth is obtained in a much shorter time when silica is added to the medium than when it is absent.

Haldane,[24] referring to statistics compiled in England in recent years concerning occupational mortality, says that, since the inhalation of siliceous dust leads to tubercular infection of the lungs, with great development of fibrous tissue, deaths from silicosis are nearly all returned as due to phthisis or tubercular lung disease, but that there is clear evidence that the inhalation of siliceous dust leads, or may lead, to deaths returned as due to bronchitis. Although bronchitis is not silicosis, a high bronchitis may be associated with silicosis as well as with inhalation of various sorts of dust. He also states that, although available statistical evidence does not show the existence of any silicosis among coal miners, other direct evidence has shown in recent years that in exceptional circumstances very great risk may occur among men driving roads through sandstone or other highly siliceous rock. However, he evidently attributes the high mortality among coal miners from bronchitis to the severe muscular exertion rather than to the inhalation of coal-dust. The chance of death from bronchitis is about seven times as great among the more or less unskilled who work mainly with their legs and arms, as among the classes whose occupation involves but little hard muscular work. He concludes, from the fact that functional efficiency increases, that presumably a collier's or a cement worker's lung becomes more efficient as

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23 - See footnote 22.

24 - Haldane, J. S., Silicosis and Coal-Mining: Trans. Inst. Min. Eng., London, Feb., 1931, pp. 415-451.

regards its phagocytic activities than the lung of a person not exposed to dust; and this accounts for the relative immunity to phthisis of a coal miner or coal-boat loader or cement worker. He supposes that some soluble constituent in the dust stimulates the phagocytes to activity and that this substance is present in coal-dust, shale-dust, clay, and various other kinds of stone which are not harmful. He found that the Registrar-General's statistics showed a higher bronchitis death rate among anthracite miners, although there is no rock-dusting in the district, and thought that possibly the anthracite-dust is in some way more irritating or penetrates more readily than ordinary coal-dust. Haldane summed up his conclusions as follows:

> Neither the Registrar-General's statistics nor any other evidence whatsoever shows that any class of work in coal mining is subject to risk from silicosis except under very exceptional conditions that can be guarded against effectively. Nor is there any clear evidence that dust inhalation by coal miners is an ordinary cause of either bronchitis or pneumonia among them, although it seems practically certain that excessive inhalation of coal dust or shale dust must cause bronchitis, and ought therefore to be avoided.

In the discussion of his paper Haldane made the following statement in regard to X-ray diagnosis of silicosis:

> This paper, although it is about coal mining, has a good deal of bearing on metalliferous mining as well. It has been shown lately that when healthy coal miners are examined with the X-rays, a good many of them present a picture which can not be distinguished from the picture seen in the case of the Johannesburg miners. If a man in the mines at Johannesburg presented such a picture, it would be regarded as sentence of death, but this picture seems to be found in this country among coal miners who are fairly healthy. I want to make a strong protest against the practice of diagnosing silicosis on mere X-ray examination without knowledge of the man's history and of the kind of dust he breathes. One is apt to get into the hands of X-ray specialists who diagnose silicosis in all sorts of cases. There is a considerable tendency at present to say that working in stone is a dangerous occupation, when it is not dangerous as a general rule, although it may become so in certain definite circumstances. Recent legislation seems to invite endless compensation litigation, in the midst of which there is a possibility that the real cases of silicosis may be missed entirely. It would be very difficult for a doctor--say, in panel practice--to affirm that a case is not silicosis; there would be a natural tendency to give patients the benefit of the doubt. I look with some apprehension on regulations that are being introduced on this subject; at all events, they call for great skill and care in administering them, and for greater knowledge than to-day exists among a number of the specialists.

Wynne,[25] in the course of the discussion of Haldane's paper, asked whether it is possible for an accurate diagnosis of silicosis to be made before a man dies, and mentioned a case from a pottery district in which a man had been working all his life and, from his industrial history, could not have been anywhere near rocks containing any appreciable or dangerous proportion of free silica, or engaged in any processes likely to be dangerous. Unfortunately in view of the unanimous opinions of the three doctors in certifying him to be suffering from silicosis, the coroner decided that a post-mortem was unnecessary.

The following statement was made by Jones[26] during the discussion:

> With regard to X-ray photographs, I think I am right in saying that on the Rand, of the cases which have been subject to a post-mortem examination, over 30 per cent of those which had been diagnosed solely on X-ray photographs have been proved to be wrong; and that a large amount of money had been paid in compensation which need not have been paid. Just before Christmas I heard of a case in which a man was said to have died of silicosis, but on going through his history it was found that this man had never worked in any rock containing more than 40 per cent of free silica. On port-mortem examination, however, the man was found to have actually suffered from silicosis. In that case the X-ray examination was backed up, but owing to legislation no compensation could be claimed by the relatives of the deceased.
>
> The question of anthracite-dust is rather interesting. I might refer to one case in which a death occurred, and the verdict of "natural causes" was returned at the inquest. The doctors regarded the death as due to some bronchial trouble, but on post-mortem examination this man, who had been working on the screens at an anthracite colliery, was found to have a tremendous amount of anthracite-dust in his lungs; his lungs were full of dust, yet the medical people said that that was not responsible for his death.

According to Collis[27] figures for bronchitis differ widely, and in order to accord with the somewhat novel idea advanced that liability to bronchitis depends upon muscular exertion, would require that the muscular work done on the Nottinghamshire coal field should not only be far less than on the Lankshire and South Wales fields, but also less than the standard set by occupied and retired males. The data, according to Collis, can hardly be claimed to be in support of the "muscular exertion" theory of bronchitis among coal miners; hence the final conclusion of Haldane seems to be reinforced that "it seems practically certain that excessive inhalation of coal-dust or shale-dust must cause bronchitis, and ought therefore to be avoided."

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[25] - See footnote 22.
[26] - See footnote 22.
[27] - See footnote 22.

A case is reported by Edwards[28] of a man aged 32, who had been a gravedigger for 17 years. He died from what was manifestly silicosis associated with tuberculosis. During his work he had to make graves in red sandstone, and pneumatic drills were often employed for this purpose; in dry weather the work was so dusty that he and his colleagues were able to work for periods of only 20 minutes.

A preliminary study, confined to the examination of men in working health and intended as a basis for any subsequent investigation into the radiographic appearances in the chest diseases of coal miners, was carried out by three selected teams of the medical staff of the Welsh National Memorial Association.[29] Chest radiographs of healthy coal miners were compared with those of persons not exposed to coal-dust. The following general program of work was carried out:

1. To discover, by the examination of coal miners (preferably over 40 years of age) who have been working as hewers for a period of 15 years or over, but excluding men who have worked in hard headings, whether they show abnormal X-ray appearances, these appearances, nevertheless, being consistent with ability to work.

2. To ascertain whether, in the case of coal miners of the foregoing groups, abnormal X-ray appearances are found to be associated with alterations in chest expansion and general physique; or with alterations in vital capacity where facilities for recording the latter are available.

Groups of healthy coal hewers from anthracite collieries, steam coal collieries, and semibituminous collieries to be studied in relation to the following points:

Details of Employment.-- (a) Duration of employment as worker in coal. (b) Capacities in which employed, with length of time: dusting, hewer, etc. (c) Kind of coal worked, e.g., semibituminous, steam, anthracite.

Physical Records.-- (a) Standing height without boots. (b) Chest measurement at nipple line in full expiration and full inspiration. (c) Weight in shirt and trousers. (d) Spirometer records where obtainable.

Standardized X-Ray Technic.-- (a) Position of patient: standing with tube to back, arms drawn forward and rotated inward to remove shadows of scapulae. (b) Phase of respiration: partial inspiration.

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[28] - Edwards, P. W., Silicosis in a Gravedigger: Lancet, vol. 1, 1931, pp. 1238-1239.

[29] - The King Edward VII Welsh National Memorial Association. Coal Miners' Lung; A Radiographic Study of Certain Groups of Industrially Healthy South Wales Coal Miners: Jour. Ind. Hygiene, vol. 13, Jan., 1931, pp. 19-45.

(c) Position of tube: focus of tube centered at level of third chondrosternal joint. (d) Film target distance: 30 inches, approximately (duplicate at 36 inches in certain type cases). (e) Spark gap: 4 inches, approximately. (f) Current: 20 milliamperes. (g) Exposure: will vary with thickness of patient. (h) Screen: double intensifying to be used. (i) Films: kodak-contrast. (j) Developer: kodak. (k) Fixing: kodak. (l) Time and temperature of developer: approximately six minutes at 65°F.

The following is a general summary of the results of the comparison of the four groups--three groups of coal miners and one of the agricultural workers:

> The mottling present in the anthracite workers is over twice that in the workers in steam coal, and it seems probable that further research will be necessary to elucidate the cause or causes of such a marked difference.
>
> From these investigations and comparisons it seems certain that within the span of a miner's working life and while he still retains what may be called working health, exposure to the dust of the coal mines, and, perhaps, especially to the dust of the anthracite coal mines, leads to marked alterations in the lungs, visible in X-ray films and comparable, in many respects, to the alterations regarded as characteristic of silicosis. That such appearances are consistent with working health is a fact which has a very important bearing upon the interpretation of radiographs in cases of pneumonoconiosis.
>
> With prolonged exposure to the inhalation of coal-dust and the dusts associated with it in the mines, and with the development of lung fibrosis as seen in X-ray films, there goes a tendency to a gradual deterioration which, though insufficient to lead at once to industrial disability, becomes apparent in diminished chest expansion, lowered vital capacity, and some loss of weight.
>
> The data for the South Wales coal field are subdivided into three districts which comprise: (a) the eastern or Monmouthshire area, wherein most of the coal got is soft bituminous or house coal; (b) the mid or Glamorgan area, wherein most of the coal got is steam coal; and (c) the western area, wherein a large proportion of the coal is anthracite.
>
> Hewers or coal getters, at least on the South Wales coal field, are mainly exposed to the dust arising from the coal they work; as will be seen in the Team reports, however, they may sometimes perform duties which involve exposure to stone-dust as well. Mortality records for pulmonary diseases among hewers employed in the three areas of South Wales may be claimed, in so far as they differ from each other, to give some indication as to whether dusts from the three types of coal named exert different pathologic effects.

The standardized mortality figures for these three areas indicate that English coal miners on an average suffer decidedly less than the standard set by occupied and retired males from respiratory tuberculosis, about the same from pneumonia, but definitely more from bronchitis. When the three South Wales areas are considered, the western area, that reported on by Doctor Jordan and Doctor Clark, is found with figures for each of the diseases not only above those for the other two areas, but above those for all the other fields, and for occupied and retired males, the excess being greatest for bronchitis.

An excess of bronchitis, when compared with that experienced by all occupied and retired males taken as a standard, is found among coal hewers aged 45 years and over. This excess is most pronounced in the western group, while the Glamorgan hewer suffers more than his colleague in Monmouth from this cause of death.

Coal hewers of the western group experience an excess death rate from pneumonia at ages 45 to 75. An excess for the Glamorgan and Monmouth hewers is present only at ages 65 to 75.

Although, as is usual for coal miners, the three groups of coal hewers experience no excessive death rate from respiratory tuberculosis, a slight excess is present for the western hewers.

In the absence of any other contributing influence, the trend of these records would support a contention that occupational exposure to dust from anthracite coal mining exerts a definitely injurious effect on the lungs, which increases with age, and expresses itself particularly in mortality from bronchitis and to a less extent in mortality from pneumonia and from respiratory tuberculosis. Dust of mining in bituminous and semibituminous coal does not appear to exert this influence to the same degree, although some undue mortality in late life from bronchitis is associated with it.

Germany.- Flatzeck-Hofbauer,[30] director of the hospital for the care of the tubercular patients in Bavaria, in the center of the porcelain industry, although assuming with other authors that pneumoconiosis appeared relatively less frequently among granite workers than among sandstone workers, decided to determine whether "severe" dust-lung diseases were present in general within the meaning of the law in regard to the sandstone industry. He was able through the local labor organization to examine 10 very old granite stone cutters. Of these men who had occupational history of having worked from 31 to 49 years in granite only, one showed "moderately severe" and another "moderately severe to severe" silicosis. With the other seven the degree of silicosis present had to be considered more or less definitely as "severe." In five of these seven there was definite complication with tuberculosis.

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30 - Flatzeck-Hofbauer, Alfred, "Severe" Occupational Dust Lung Diseases: Zentralb. Gewerbehyg. u. Unfallverhütung, vol. 18 (new series, vol. 8), No. 5, May, 1931, pp. 116-119.

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According to the author, this frequency of lung tuberculosis (dust-lung tuberculosis) among old granite stone cutters should be a completely valid proof of the danger of breathing granite-dust and must be considered as indicating without doubt that dust-lung diseases qualifying for compensation are present among granite stone cutters also, and not among sandstone cutters alone, as the severe tuberculo-silicotic total diseased lung condition is similar to the severe dust-lung diseases (without tuberculosis) that come under the decrees of the Government insurance office.

Menslage[31] calls attention to the fact that injury to health can occur through the purely physical action of the large amounts of dust arising during the utilization of all kinds of abrasive substances. The really injurious silicosis can appear as a rule only with the use of natural sandstone; the dust of artificial abrasives, due to their extremely small content of free silica, is not in a position to cause silicosis. This is of interest for the prevention of accidents (prevention of occupational diseases) as well as for the fixing of compensation. In regard to the first, it is to be considered whether the spread of silicosis can be reduced through the substitution of artificial abrasives for natural stone. In regard to the latter, physicians, insurance carriers, and compensation courts must consider together the question as to whether silicosis is present among the polishers, also the kind of abrasive used.

After an exhaustive survey of the work on pulmonary asbestosis in other countries, Krüger, Rostoski, and Saupe[32] give an account of the work done in Germany, together with a short statement of cases of the disease coming under their own observation in Dresden. They state that -

> The first record in Germany was a demonstration by Fahr to the Medical Society of Hamburg in 1914 of specimens and photomicrographs of a case of pneumonoconiosis in an asbestos worker. Fahr mentioned the occurrence of a large number of crystals in the lung but did not describe them more closely. He stated, however, that they had been seen by Marchand and Riesel in 1906, who had speculated as to whether they were due to the inhalation of asbestos dust or were a haemoglobin derivative. In 1931 Büttner-Wobst and Trillitzsch described nine cases occurring in two asbestos factories near Dresden. Meanwhile the authors of the present paper had begun to collect cases. They have now examined 52 (18 male and 34 female) workers, of whom 30 showed definite lung changes. A short analysis of the history of these cases is given. The longest exposure to the dust was 31 years in a worker aged 60.

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31 - Menslage, ___________, Danger to Health Through Abrasive Dust, with Special Consideration of Artificial Abrasive Substances and Silicosis: Zentralb. für Gewerbehyg. u. Unfallverhütung, vol. 18 (New series, vol. 8), No. 5, May, 1931, pp. 123-125.

32 - Kruger, E., Rostoski & Saupe, Ueber Lungenasbestose: Arch. Gewerbepath. u. Gewerbehyg., vol. 2, Berlin, 1931, pp. 558-90. Quoted from Ind. Hygiene, vol. 6, p. 861, Dec., 1931.

Beintker[33] records two cases, with post-mortem examination, of pulmonary asbestosis occurring in a factory concerned with the crushing, cleansing, and spinning of asbestos and the manufacture of insulating materials. He reached the following conclusions from these cases:

> Asbestosis of the lung differs from silicosis in its radiological picture as well as in anatomical findings in that the connective tissue increase is very diffusely distributed. It is arranged in nodules in silicosis, whereas in asbestosis it is distributed diffusely throughout the lung. The actual morbid anatomy picture appears to depend upon the distribution of the asbestos fibres in the lung tissue, and it is assumed that the asbestos fibres which gain access to the tissues probably do not begin their development into bodies until they reach the tissues. They are apparently the accumulation of the silica-containing material. The author believes that the X-ray picture in all types of silicosis, including asbestosis, depends not so much on the quantity of the thickened tissues as its distribution in the lung. Diffuse distribution does not give the same intensity of shadow to the radiological picture as does the nodular distribution. He suggests that the fibrosis of the lung tissue develops, in asbestosis, through the breaking down of the material of the asbestos fibres into SiO_2.

Italy.- According to the report of Loriga[34] to the International Conference on Silicosis held in Johannesburg in 1930, the study of pneumoconiosis has not been so extensive or profound in Italy as in certain other countries, especially the Anglo-Saxon countries. He considers this to be due to the fact that in Italy the composition of the minerals extracted or worked presents a relative poverty of siliceous material, and is not due to a limited number of workers engaged in dusty operations, or to hygienic conditions superior to those of other regions. Loriga states that information relative to hygienic conditions obtaining in the workers' homes and in the work places, and duration of exposure of the worker to the action of the dust, may play a preponderant role when the study of the disease has been completed by enquiry into the physical and environmental conditions. He mentions asbestos workers, slate, sulphur, and mercury miners as most exposed to injurious dust, but states that a true dust pneumoconiosis does not occur among marble workers.

Lovisetto[35] reported investigations of conditions of workers in the asbestos industry from 1902-1912 and from 1912 to the present with the following conclusions:

> In the second period extending from 1912 to the present time and following on the erection of a factory construction complying with

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[33] - Beintker, E., Die Asbestosis der Lungen: Arch. Gewerbepath. u. Gewerbehyg., vol. 2, Berlin, 1931, pp. 345-58. Quoted from Ind. Hygiene, vol. 6, p. 863, December, 1931.

[34] - Loriga, Giovanni, Pneumoconiosis in Italy; Silicosis: Rec. Internat. Conf. Johannesburg, Aug., 13-27, 1930, pp. 481-504.

[35] - Lovisetto, Domenico, Pulmonary Asbestosis: Rec. Internat. Conf. Johannesburg, Aug. 13-27, 1930, pp. 506-509.

the most hygienic modern precepts, conditions among the workers have greatly improved and further the workers were only engaged after selection by thorough medical examination. It must also be remembered that the periodical medical examination reveals at the outset the presence of morbid symptoms, even when these are still very slight.

In conclusion, inhalation of asbestos-dust in the long run causes pneumoconiosis; the period required for the manifestation of this pathological state is at least five years. There is a direct ratio between the quantity of dust inhaled and the pneumoconiosis; the higher the dust concentration the less time is necessary for the manifestation of fibrosis. It can reach complete development after a period of seven to nine years and it can cause death after 13 years on condition that the individual is continuously exposed to the risk in a very dusty atmosphere.

When the cause of the inhalation of the asbestos-dust is withdrawn the pneumoconiosis process is generally arrested.

The functional injuries caused by the inhalation of asbestos-dust occur very slowly and are characterised by dyspnoea on effort, and by a slight insufficiency of the right heart, the patient after being attacked may work for a long time with brief spells of rest.

It is very doubtful whether pulmonary asbestosis favours the occurrence of acute pulmonary affections though the anatomical conditions of the sclero-fibrous lung which cause a slowing down of the blood circulation in the lung (pulmonary stasis) may justify the supposition of a more ready development of the pathogenic germs in the respiratory passages.

Pulmonary asbestosis is a disease in itself which must not be confused with other diseases of the lungs; it is an occupational disease noninfectious and noncontagious. It is of slow progressive evolution, but when the irritant action of the asbestos dust inhaled has ceased the fibrous process is generally arrested.

Cases with a fatal issue are rare and at the present time, with modern means of protection, with highly perfected exhaust and ventilation apparatus they should no longer occur.

Pulmonary tuberculosis is on the other hand an infectious disease of slow progressive and quite characteristic evolution; and the anatomopathological data and pathogenesis are likewise typical.

It may be conceded that the inhalation of particles of asbestos, by causing chronic irritation of the respiratory passages of the lung, may favour in a limited number of cases, installation of the Koch bacillus.

According to Turano,[36] who examined 105 workers, the changes met with among Carrara marble workers may be classed in the initial stage of pneumoconiosis; that is to say, they comprise the least serious forms of the disease, such as the very marked reinforcement of the pulmonary outline, due as demonstrated by personal observations, to the processes of arteritis and lymphangitis, and in certain cases equally to conditions of emphysema usually present among those workers.

There have also been found frequent pleuritic changes which can be related to inhalation of marble-dust, but never, however, lesions of the pulmonary parenchyma. The radiological aspect of pulmonary tuberculosis among the workers examined is, on the other hand, highly important, since it shows an atypical picture on which are noted lesions with unusual sites and apical and subclavicular regions unaffected. It is this fact which has led to the admission of the probability of a combination of pneumoconiosis and tuberculosis.

Finally, statistical as well as radiological data justify, according to Turano, absolute exclusion of the theory of a particular benign or malignant course of tuberculosis among marble workers, as likewise of any kind of predisposition to the said specific disease.

Zanelli[37] describes the case of a workman employed in a pneumatic tire factory to inject powdered talc into the interior of the tires and to apply the same material to the outer surfaces of the tires by means of a cloth. During this work, the air contained a dense dust, but no masks were provided for the employes and no other means was adopted for their protection from the dust. The man developed grave digestive troubles, and X-ray examination of the lungs revealed the presence of the nodular formations typical of pneumoconiosis. Although talc has been regarded as a mineral forming a dust which only rarely has pathogenetic qualities, one of its properties seems to render it particularly dangerous. It forms extremely minute particles which do not irritate the sensitive nerve endings of the mucus on which they are deposited, so that such important means of defense as sneezing, coughing, and increased secretion are not brought into operation. In the case considered, indeed, the patient exhibited during work hours a weakening of the olfactory sense, the layer of dust on the mucus preventing the transmission of the olfactory stimuli to the nerve endings.

Netherlands.- The stonemasons act of 1911 and 1921, according to Kranenburg,[38] requires every stonemason under 21 years of age to have a stonemason's card, which is issued to him after a free medical examination, if the performance of this kind of work apparently will not be especially dangerous to his

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36 - Turano, Luigi, Radiological and Clinical Studies Effected Amongst the Carrara Marble Workers: Rec. Internat. Conf. Johannesburg, Aug. 13-27, 1930, pp. 509-511.
37 - Zanelli, Arturo, Pneumoconiosis Caused by Talc: Nature, vol. 127, London, May 16, 1931, Research Items, p. 759.
38 - Kranenburg, W. R. H., Silicosis in the Netherlands: Rec. Internat. Conf. Johannesburg, Aug. 13-27, 1930, pp. 512-534.

health. Adult stonemasons, those 21 years of age and over, must be examined; but a card is issued, irrespective of the results of the examination. A periodical examination of adult workmen takes place at the expiration of three years from the time the stonemason's card was issued. The first general examination of stonemasons took place in 1923, the second in 1926, and the third in 1929, so that it has been possible, although not in a large number of cases, to compare the clinico-physical condition of the lungs of the same person at the three dates with the three X-ray photographs. Kranenburg states that the results show that in nearly half the cases the X-ray examination gave more information than the physical examination. In a corresponding statement concerning 69 cases from the general examination in 1929, lung affections are not shown clinically in 19 cases, but are shown in the X-ray examination, and in 38 cases both clinically and by X-rays. He makes the following statement in regard to signs and symptoms:

> It is noticeable that in the general examination of stonemasons in 1923, 1926, and 1929, few complaints were received as to the state of health of the patients; most of them felt quite well, though a certain number complained of shortness of breath when moving. Here and there men complained of coughs with little or no sputum, which explains why altogether an examination of the sputum was made in only 48 cases, with positive results as to the presence of tubercle bacilli in 11 cases. After inhaling stone-dust for many years, complaint was made of irritation in the throat and a stifling feeling in the breast, with relative shortness of breath, an inclination to cough and expectoration, especially on rising in the morning. Generally speaking, percussive irregularities are few and auscultatory phenomena more striking: rough, heightened or weakened respiratory rustling, lengthened or jerky breathing in one or both apices or other places, also cracking and dry snoring noises, varying in strength and area, seldom damp or crapitating. Coughing and sputum which is not characteristic often only occur when bronchitis appears as a complication.
>
> The X-ray picture of pneumonoconiosis, due to the dust of various kinds of stone, does not differ in its various degrees from those given for silicosis by various investigators: (1) enlarged hilus-shadow, increased appearance of the retiform tissue and linear shadows; (2) increased appearance as in (1), and the appearance over a wide area of stippled shadows (mottling), and (3) appearance as in (2) and nodular shadows, large close mottling.
>
> The question of the mutual relations between pneumonoconiosis and tuberculosis, whether the tuberculosis only appears in later years as an infection on a foundation of silicosis--tuberculo-silicosis--or the silicosis is secondary to tuberculosis latent in youth and manifesting itself later--silico-tuberculosis--appears to be more and more answered in this sense, that each of the two processes favors the development of the other, and that the tubercle bacillus, appearing as a secondary factor, often seriously threatens health and life. In this connection the case is noteworthy of a stonecutter 47 years old who, on a clinical

and X-ray examination, showed an affection of the apex of the right lung without exhibiting radiologically any degree of silicosis after 34 years' work on sandstone.

Kranenburg's general conclusions are as follows:

The introduction and application of the stonemasons act has led to a clearer insight into the character of the "stonemasons' disease" and a more intelligent procedure in combating it by the improvement of the working conditions and personal hygiene of stonemasons.

The preliminary medical examination and annual re-examination of young stonemasons to a considerable extent prevents persons suffering from lung tuberculosis entering upon and continuing in stonemasons' work.

The periodical (three yearly) medical examination of adult stonemasons has shown the indispensability of X-ray examination for forming an opinion of lung affections.

The working of sandstone alone must be regarded as more injurious to the lungs than the working of limestone alone. The working of sandstone alone does not always lead to symptoms of silicosis and, on the other hand, the working of limestone alone (Belgian limestone, marble) does not prevent silicosis in a serious form. The working of sandstone and limestone alternately appears to produce less serious results in the same period than the working of sandstone alone.

Compulsory medical examination both in the form of preliminary examination and periodical re-examination should be introduced for sandblowers as well as for stonemasons.

Silicosis as an occupational disease of stonemasons should be assimilated to an accident for the purposes of the application of the accident act.

United States.- In studies on the effect of inhalation of asbestos-dust on tuberculous infection, Gardner and Cummings[39] demonstrated that fibrous structures at least as long as 200 microns can pass the protective mechanism of the upper respiratory tract and enter the lungs. Asbestosis bodies are not present in asbestos-dust previous to contact with animal tissues; they are produced by oxidation and hydrolysis of the chrysotile molecule.

In these studies it was found that asbestosis bodies, apparently identical with those described in the human being, have developed in guinea pigs after an exposure of approximately 70 days. In the rabbit these structures have not been discovered after exposures of as long as 330 days. In the albino rat

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39 - Gardner, L. U., and Cummings, D. E., Studies on Experimental Pneumonokoniosis: VI. Inhalation of Asbestos Dust: Its Effect Upon Primary Tuberculous Infection (Concluded): Jour. Ind. Hygiene, vol. 13, No. 3, March, 1931, p. 111.

they are very rare. Only two small typical forms have been discovered in one animal exposed for 70 days. The prevalence of chronic infections of the lung in all members of this series is possibly responsible. It was found that primary tuberculous infection is influenced only to a limited degree by inhaled asbestos, but the combined action of asbestos-dust and tubercle bacilli in the lung produced more fibrosis than did either agent acting independently.

According to Boultman,[40] sand blasting is an occupational hazard due to the dusty, insanitary conditions that are unavoidable with the primitively designed equipment still being used at many plants. He divides the problem into four factors: (1) The abrasive, and facilities for keeping it clean and free of dust; (2) design and condition of equipment; (3) ventilating facilitie for removing dust from the blasting chamber; and (4) protective equipment for the operator. He calls attention to the fact that the best silica sand offers little resistance to shattering and in many cases the dust from the shattered silica-sand abrasive exceeds the dust removed from the surface being blasted; the result is that the dust concentration in the sand-blast chamber is excessive, even with liberal ventilation, so that visibility is poor and production retarded. Steel abrasives themselves make no dust, they eliminate entirely all dust caused by the shattering of the abrasive, and thus eliminate 50 to 90 per cent of the dust created when silica sand is used. In regard to safety equipment, Boultman states that operators naturally look for convenience and, mainly through ignorance of consequences, disregard the merit of equipment which provides the best protection. The employer knows the relative merits of the various kinds of protective equipment, and therefore, as he is in a better position to select the proper protection, he should decide on the equipment and insist upon its use.

In an article on the chemical-engineering control of industrial lead poisoning, Safety Engineering[41] states that the skill and experience of industrial physicians are highly important essentials in the prevention and control of lead poisoning, as medical knowledge is invaluable in the detection of the early symptoms of lead absorption and as the physician is the only one who can prescribe suitable treatment for leaded employees and administer it with the best possible results. It is also within the province of the physician to make a study of the plant, to classify the operations and working locations according to the severity of the exposure, and to arrange for the transfer of affected employees to lead-free areas. The article also points out that engineering control of lead poisoning does not stop with the correction of physical exposure, the provision of safety devices, or the establishment of welfare and hygienic aids. Over and above all, a definite and proper mental condition must be created which will cause executives and supervisors to realize the importance of preventive measures - that they are part and parcel of the productive program. Moreover, the employees must be so educated that they will be convinced that lead absorption or poisoning is wholly avoidable and unnecessary, and that compliance with mandatory orders and plant instructions is for their personal benefit because it will increase their welfare and efficiency. In conclusion the article states that the chief essentials for success in controlling lead poisoning or lead absorption are the close coordination of the plant physician and the engineer, and sincere company-executive participation in the execution of any program of control that may be developed. Good physical conditions, sanitary surroundings, proper medical service, and skilled engineering supervision can attain the sought-for objective.

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[40] - Boultman, Charles, Dust Prevention and Suppression in Sand Blasting: Address before the Fourth All-Ohio Safety Congress and Exhibit, Columbus, Ohio, April 22, 1931.

[41] - Safety Engineering, The Chemical-Engineering Control of Industrial Lead Poisoning: vol. 62, No. 2, Aug., 1931, pp. 104-109.

Washington University, in cooperation with the Research Laboratory of the American Society of Heating and Ventilating Engineers,[42] is undertaking the development of a more sensitive and accurate method of determining air dustiness. This work has been under way during the past year and gives promise of very valuable developments.

The Technical Advisory Committee on this subject has been actively engaged in developing a program for future activity. Its plans include the development of a code for testing air-cleaning devices, but since no instrument now on the market is entirely satisfactory for all purposes, it is proposed by the committee to cover by specifications the design of an instrument of a jet-impingement type for industrial and field work, and of an instrument of the filter type for investigation of atmospheric pollution. The committee hopes to correlate the various interests and activities in the field of atmospheric dust and smoke study.

Pancoast and Pendergrass[43] give the following conclusions from their review of pneumoconiosis:

> 1. The subject of pneumoconiosis has been reviewed from the standpoint of its etiology, its pathology, and its roentgenographic appearances.
>
> 2. Pneumoconiosis is a more or less necessary risk of commercial development in the progress of civilization, but its progress and serious aspects may be lessened by certain preventive measures in most instances. Its incidence in many industries apparently can not be altogether eliminated.
>
> 3. It has aroused widespread interest and has received a great amount of study during the past few years.

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[42] - Heating, Piping and Air Conditioning, Atmospheric Dust and Air Cleaning Devices (Report of the American Society of Heating and Ventilating Engineers Research Laboratory, June 1, 1931): Aug., 1931, pp. 702-703.

[43] - Pancoast, H. K., and Pendergrass, E. P., A Review of Pneumoconiosis; Further Roentgenological and Pathological Studies; Reprinted from Am. Jour. Roentgenol. and Radium Therapy, vol. 26, No. 4, Oct., 1931, pp. 556-614.

4. The roentgenological examination is the most important and accurate means of detecting its presence, especially in early cases, of studying its progress and of determining its extent and severity. Rapidity of progression is easily determined by serial study.

5. Roentgenology will be employed more and more extensively as the necessity of study of workers in hazardous industries becomes realized and regulations for protection and compensation laws are adopted in this country. The roentgenologist must be experienced in his work and honest in the expression of his opinions.

6. It behooves the roentgenologist to become thoroughly familiar with the subject from every angle. The particular hazards of certain industries must be understood and the roentgenographic appearances more or less characteristic of some of them must be learned.

7. Roentgenographic appearances are the expressions of pathological changes, and to properly interpret them requires an intimate knowledge of the pathology of the condition. A resume is given of the present exact knowledge of the pathology of pneumoconiosis based upon autopsy study and animal experimentation. Various theories advanced in explanation of some uncertain points are given brief consideration.

8. Various classifications of the degrees of progress of the condition are in use in different countries. Most of these have a clinical basis with which roentgenographic appearances must be made to conform. No one of them seems adequate or entirely satisfactory in its application to every dusty industry, especially from the standpoint of the roentgenologist. A new pathological-roentgenological classification is proposed, or at least offered as a suggestion.

These authors state that they seem to have authority for two actions of coal-dust - it retards the action of silica when there is a slow intake of the latter, and it enhances its action when the intake of silica is rapid. In regard to the alleged protection directly or indirectly afforded by coal-dust against tuberculosis they make the following statement:

> If there is any protection in the industry, it probably arises from other factors. The important ones, at least in one district, are well embodied in an old paper by Wainwright and Nichols, in 1905. In seeking a cause for the supposed protection against tuberculosis in the anthracite regions of Pennsylvania, they finally concluded that it was an actual fact, probably due to several factors. As contributing ones they suggested the following: The absence of crowding at work; lack of extreme overcrowding in housing; the custom of these miners in walking or riding considerable distances; the forced daily bath because of the black dust accumulated on the body each day; the moisture of the mines preventing sputum from drying and the gradual bacterial purification of the air from mine entrances to the working chambers. Animal

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experimentation suggested that the coal-dust offered some protecting influence against tuberculosis through the stimulation of a mild fibrosis, which they thought was the essential factor, but coal-dust had no direct bactericidal action.

Meriwether and Sayers[44] call attention to the difficulties in diagnosis of the early stages of silicosis, as the development of the disease may extend over a period of years and be so gradual that the early symptoms are often not recognized by those so afflicted or are considered to be such a slight departure from the normal that they are not important. As the disease progresses, the clinical symptoms become more definite, and those afflicted recognize that there exists some condition which interferes with normal working efficiency. With further progress of the disease, the working efficiency becomes so markedly affected that there is in many cases total disability. In this stage there is a definite tendency to develop complications, particularly tuberculosis or infective silicosis. The slow progress in the development of the disease has caused observers in this country and abroad to divide the disease into three stages - first, second, and third. In regard to the use of the X-ray in diagnosis, the statement is made that the value of the X-ray method of diagnosis is largely dependent upon the skill of the technician making the pictures and the experience of the reader in interpreting them. With efficient technic in the operation of the X-ray machine and with a fair amount of clinical experience, the physician can make a definite diagnosis of silicosis by the X-ray alone and can distinguish it from other chest pathology with reasonable certainty. The treatment recommended for silicosis is preventive and curative. The prevention treatment lies entirely in protecting the workers from exposure to unduly large amounts of dust and in giving a yearly physical examination in order that they can be warned on the first evidence of silicosis to change their occupation to a nondusty one. In the early stages the curative treatment is to remove them from the dusty occupation, and in the later stages symptomatic treatment gives some relief.

In a study to determine the percentage of dust or fume retained at concentrations of less than 50 milligramsper cubic meter, the following results are reported by Brown:[45]

> Four hundred and twenty-two experiments on the retention of magnesium oxide fume and of calcium carbonate (marble) dust by 32 subjects breathing normally while at rest, through the mouth while resting, and normally during exercise and during the inhalation of approximately 5 per cent carbon dioxide in the air gave the following results:

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44 - Meriwether, F. V., and Sayers, R. R., Silicosis: Jour. Oklahoma State Med. Assoc., vol. 24, Oct., 1931, pp. 317-324.

45 - Brown, C. E., Quantitative Measurements of the Inhalation, Retention, and Exhalation of Dusts and Fumes by Man; II. Concentrations Below 50 Mg. Per Cubic Meter: Jour. Ind. Hygiene, vol. 13, Oct., 1931, pp. 285-291.

The percentage of magnesium oxide retained during normal breathing while at rest varied from about 60 per cent at a concentration of 10 milligrams per cubic meter to 45 per cent at 50 milligrams per cubic meter. The percentage of calcium carbonate retained under the same breathing conditions varied from about 80 per cent at 10 milligrams per cubic meter to 70 per cent at 50 milligrams per cubic meter.

The percentage retention for mouth breathing while at rest and for normal breathing during exercise and during carbon dioxide inhalation was about 10 per cent less than for normal breathing while at rest under the same conditions.

The percentage retention changed but little at concentrations above 50 milligrams per cubic meter, but apparently rapidly approached 100 per cent as the concentrations fell below 10 milligrams per cubic meter.

A further study[46] of the above data, to explain the differences noted and to determine some of the factors that influence the retention of inhaled dusts and fumes, gave the following results:

Analysis of the data obtained from 418 dust-retention experiments using magnesium oxide in 363 and calcium carbonate in 55, and employing 32 subjects breathing normally, shows that percentage retention varies with certain measurable factors:

1. Percentage retention is inversely proportional to respiration rate for rates below 20 per minute. An increase above 20 per minute is apparently followed by no change in percentage retention.

2. Percentage retention is inversely proportional to minute-volume of air breathed. This effect probably results from the increase in respiration rate with minute-volume.

3. Percentage retention is directly proportional to particulate size (not particle size) and to density of dust suspended in air.

4. Percentage retention is directly proportional to extent to which the dust is wetted in passing through water.

The results also show that percentage retention apparently is not affected by the following factors:

1. Volume per respiration.
2. Vital capacity.
3. Relative humidity of inspired air.

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46 - Brown, C. E., Studies in Dust Retention; III, Factors Involved in the Retention of Inhaled Dusts and Fumes by Man: Reprinted from Jour. Ind. Hygiene, vol. 13, No. 9, Nov., 1931, pp. 293-313.

Published data on dust retention obtained by other investigators are summarized, but owing to the lack of essential information it is not possible to compare the results with those obtained in the present study. A chart summarizing the data on magnesium oxide and calcium carbonate is presented as a graphic aid in estimating dust retention by man.

In an article on the dusts encountered by the heating, piping, and air conditioning engineer, Spafford[47] calls attention to the "intimate association" of dust with our lives. He discusses why the engineer should know what dust is, where it is, the kinds of particular concern to the engineer, and so on. He discusses "the kinds of dust with which the engineer is concerned" as follows:

> But the dusts with which heating, piping and air conditioning engineers are most concerned form but a small part of this great kingdom of dust. They are the dusts that are detectable by man. They are those which we think may have some readily observable effect upon health and comfort, which will help or hinder in manufacturing, which must be conserved because of their value, which must be removed because they are obnoxious, which must be separated as to their size in order to improve quality or maintain the standard of a product, or which must be conveyed.
>
> The largest particle of dust in this field of what we might term physiological and obnoxious dusts probably would be 72 times the diameter of the smallest particle. They might range from 1/25,000 of an inch to 72/25,000 of an inch with average dust particles 3/25,000 to 4/25,000 of an inch in size. Dust particles, however, are usually measured in microns. A micron is 1/1,000 of a millimeter or approximately 1/25,000 of an inch.
>
> In that province of the kingdom of dust known as obnoxious, objectionable, or unhealthful dust there may be grains of pollen, bits of vegetable fiber, hairs, carbon, particles of earth, ashes, particles of horseshoes and harnesses as well as automobile tires worn off on the cobble stones and pavements, threads of cotton, coal dust, shreds of wool or silk, animal excreta, smoke, water-dust, clay, stone, and materials of infinite variety and often riding on these particles are bacteria, fungi, and other living germs some harmful or beneficial or indispensable to human beings and animals; some harmless, some harmful, some beneficial or even necessary in manufacturing.
>
> One classification of dust might be as follows: Dusts from outdoors which are removed from buildings because of their effect upon human beings or animals (these have been mentioned heretofore); and manufacturing dusts; these may be marble-dust, granite-dust, mercury-dust, fumes from smelting ores, wood-dust from sanding machines and other wood

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[47] Spafford, L. B., A Review of Dust: Heating, Piping and Air Conditioning, Jan., 1932, pp. 34-35.

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operations, silica-dust, zinc oxide, fumes from plating baths, dusts from brass foundries, magnesium oxide, aluminum, chromium, iron and other oxides, particles and pigments and oils from spray painting, metals from grinding or buffing machines, fly ash, calcium-dust in a Portland cement plant, silica-dust in granite-cutting plants, carbon-dust in coal mines, vegetable-dust in a cotton manufacturing plant, and metal and other dusts in a silver polishing plant.

Some of the dusts that are the foundation of manufactured products or are usable in dust form are: Portland cement, pyroxlyn powder, bakelite powder, rubber, silica, charcoal, granulated slate, powdered coal, bone ash, soap powder, insecticides, volcanic ash, grains such as wheat, oats, rye, barley, and corn, synthetic coffee, talcum powder, toilet powder, gypsum, paints, dyes, kitchen cleanser, tungsten, litharge, wood flour, chicken feed, powdered milk, and so forth.

Clark[48] analyzed the hazard present from the use of artificial abrasives at a large grinding-wheel company, and makes the following report of a third study to review the amount of pulmonary tuberculosis that has developed in this plant during the past 13 years:

> The crystalline dust present in the workrooms is composed of aluminum oxide and silicon carbide. Careful attention to dust removal has been given where the hazard is present. No dust counts have been made. The exhaust pipes extract dust from the point at which it is produced, at a rate exceeding the stipulated 1,500 linear feet per minute wherever it is possible. There are some departments where the fineness of the product makes the engineering problem of dust removal extremely difficult, and in these departments there is a considerable amount of dust in the air.
>
> In the plant under consideration, from Jan. 1, 1918 to Dec. 31, 1930, there have been 42 cases of active pulmonary tuberculosis, 38 of which have occurred among men and 4 among women. Of the group, 37 were employed at factory work of some kind, while 5 did only clerical work.
>
> Of the 42 workers who developed tuberculosis, 20 are dead, 18 are living, and 4 can not be traced. Of the 18 living, 13 are now working, 3 are at home under care of a physician, and 2 are in hospitals. The average number of employees during the period (13 years) has been 2,460.
>
> Of the cases of active pulmonary tuberculosis developing during the period, 13 occurred among workers in departments where artificial abrasive dust was present in large quantities, and 2 occurred among those working in clay which contains 9 per cent of free silica. Twenty-two worked in departments such as the machine shop, packing rooms, etc., in which there was no dust hazard, and five were office clerks who had no contact with dust.

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48 - Clark, W. I., The Dust Hazard in the Abrasive Industry; Third Study: Jour. Ind. Hygiene, vol. 13, Dec., 1931, pp. 343-346.

Of those who developed active pulmonary tuberculosis in the departments where abrasive dust was prevalent, 3 developed symptoms in less than one year, 6 in less than four years, 1 in five years, 1 in 15, 1 in 20, and 1 in 21 years. Four of these developed the disease immediately following an attack of influenza and after very short exposure to dust. Of those working in clay-dust, one developed the disease after 12 years and one after 36 years service.

Among those working in abrasive dust departments, in proportion to the number of workers involved there were approximately twice as many cases of pulmonary tuberculosis as among those in the departments where no abrasive dust occurred. It was stated that in four of the cases in abrasive dust departments the pulmonary tuberculosis developed immediately following an acute attack of influenza. If these cases are omitted, the number which might be attributed to dust excitation of a latent process is reduced to nine, or a proportion of one and one-half times as many cases as occurred among those working in departments where there was no abrasive dust hazard.

About the only conclusion which can be drawn from the present study is that it is inadvisable for persons who have had pulmonary tuberculosis to work in a department in which large amounts of artificial abrasive or any other dust are present.

An experience of 13 years in the experimental study of pneumoconiosis has convinced Gardner[49] that the disease silicosis can be reproduced in guinea pigs and rabbits by prolonged inhalation of quartz-dust. Its production follows the daily inhalation of sufficient quantities of finely divided silica over a period of many months or years. According to Gardner,

> In the initial stages of the disease, phagocytes are more active than usual, perhaps because they are irritated by the ingested particles. They play a leading rôle in transporting the dust to points where intimate contact is established with connective tissue cells. These elements are in turn stimulated, undergo active proliferation, and develop a most extensive reticulum network. After a year has passed, degenerative changes appear in the newly formed cells with peculiar changes in the reticulum. Many of the cells degenerate, leaving a collection of coarse hyaline fibers with occasional compressed nuclei. In the rabbit, calcification is a common sequela. The degeneration is a local manifestation of the toxicity of quartz dust and not an effect of ischemia. Other toxic effects are exhibited in the rapid death of phagocytes and in the follicles of lymph nodes involved in the process. There is no evidence that poisonous substances circulate in the blood to damage the kidney and other organs.

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49 - Gardner, L. U., Studies on Experimental Pneumonokoniosis. VIII. Inhalation of Quartz Dust: Jour. Ind. Hygiene. vol. 14, Jan., 1932, pp. 18-37.

Silicosis is a progressive process when once a sufficient quantity of quartz has been inhaled.

In the development of the disease the tracheobronchial lymph nodes are first extensively damaged and largely replaced by characteristic nodular fibrosis. This interrupts the normal flow of lymph from the lungs and produces inflammatory thickening along the course of the afferent lymph vessels within the lung. Nodular lesions already started progress more rapidly within the intrapulmonary lymphoid tissues. When these structures have sufficiently enlarged, a further interference with the eliminating apparatus results and dust is implanted in increasing quantities in the alveolar walls. A "fine fibrosis" in the parenchyma of the lung is produced. In the guinea pig similar changes are brought about in the liver by dust carried to it through the blood stream. As long as its lymphatic circulation is competent, no significant reaction occurs within the organ. When its appropriate node has been obstructed, the hepatic nodules develop.

Comparative studies with other dusts have thus far indicated that only silica and the silicates are capable of exciting significant reactions in the connective tissues of the lungs. Marble, soft coal, and carborundum dusts have produced no fibrosis within periods of four years. Granite-dust acts very slowly and only in the tracheobronchial lymph nodes has it caused the formation of typical nodular fibrosis. Asbestos-dust forms collars of fibrosis about the respiratory bronchioles and proximal alveolar ducts in which it comes to rest, perhaps because of its fibrous structure.

These observations have suggested the general hypothesis that siliceous dusts excite reaction in so far as they are able to establish direct contact with connective tissues. Such contact is determined by the reaction of the phagocytes to various types of dust.

According to Kessler,[50] recently in New Jersey over 100 cases of silicosis are alleged to have occurred in the abrasive powder industry, involving four companies which pumped up sand by hydraulic pressure to a plant where it was washed, steam dried, screened into various sizes and then pulverized in closed tube mills. The free silica content of the completed product was approximately 99.24 per cent, and of the order of 1 to 5 microns in size.

While most of the claimants were employed at or near the packing operation others were in the wet processes, and several women were in the bag-cleaning work. Six persons have died and have been autopsied by Dr. Martland of Newark. Many others have been reported to have died, but the results of the autopsies in these cases are not known. Of 40 X-rays of cases reviewed by the author, only four could be called ante-primary, although some others showed varying degrees of fibrosis without characteristic mottling.

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50 - Kessler, H. H., Silicosis in the Abrasive Powder Industry: Am. Jour. Public Health, vol. 21, Dec., 1931, pp. 1390-1392.

The most outstanding feature of these cases has been the allegedly short exposure period--apparently as brief as four months to one and a half years. Others have had an exposure of as long as six years. Many of the cases have been seen by competent observers and studied by Roentgen rays and reported as first or second stage silicosis.

South Africa.- Few reports of work done in South Africa seem to have been issued since the extensive summary of the entire subject presented at the silicosis conference in Johannesburg in 1930.

Simpson and Strachan[51] report the following results from an examination of the sputum of 50 workers in an asbestos mill, some of whom also had been exposed to asbestos-dust elsewhere:

> The inhalation of asbestos-dust in high concentrations leads to the appearance of asbestosis bodies in the sputum in a large percentage of the workers exposed thereto. They were present in 48 out of 50 workers examined.
>
> Asbestosis bodies were as easily demonstrated by direct thick films as by the antiformin method.
>
> The sputum was always mucoid in character when there were no bronchial complications. It may resemble egg albumen. In none of the sputa were tubercle bacilli demonstrated.
>
> Study of the intracellular asbestosis bodies in these cases suggests that they are formed by the deposition on the asbestos fibre of an iron-containing substance elaborated by the cell.

SUMMARY OF RECENT LITERATURE ON EFFECTS ON WORKERS OF EXPOSURE TO TOXIC OR NOXIOUS GASES

In an analysis of some 270 fatal accidents due to fire damp that have occurred in Great Britain, Germany, France, and Belgium since 1928, Audibert and Delmas[52] list 37 cases of asphyxiation by fire damp.

The authors point out that although the widespread adoption of portable electric lamps tends on the whole to eliminate the dangers of fire damp ignition, it may be expected to increase the number of cases of asphyxiation. On the other hand, the relative danger, as well as the scale of mortality, is much less; again, the peril is one that can be combatted quite easily without abating the use of the electric lamp. It is significant, indeed, that in

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51 - Simpson, W. F., and Strachan, A. S., Asbestosis Bodies in the Sputum. A Study of Specimens from Fifty Workers in an Asbestos Mill: Jour. Path. and Bact., vol. 34, No. 1, Jan., 1931, pp. 1-4.

52 - The Colliery Guardian, Editorial: Vol. 140, London, Oct. 30, 1931, pp. 1478-1479.

Germany there was only one case of asphyxiation in the two years 1927 and 1928, notwithstanding that the 332,930 electric lamps in use on January 1, 1927, constituted no less than 90 per cent of the total number of lamps in use. Sixteen of the 37 accidents in this class occurred in Great Britain, but the authors confess that they are not so well acquainted with the details of these as with the 21 accidents that occurred in the same period in Germany, France, and Belgium. These accidents may be subdivided as follows: (1) Sudden outbursts of fire damp, sometimes accompanied by a fall, temporarily rendering the air in a stall incapable of supporting life; (2) cases where the worker penetrates into an abandoned and unventilated portion of the workings; and (3) asphyxiation occurring in a normal accessible working place through lack of ventilation. Of the 21 accidents, 4 were of the first type, 8 of the second, and 9 of the third. Each of these accidents is separately analyzed, and the authors think it very doubtful whether any of the first type could have been avoided by prescribing the use of flame lamps, as the warning given by the latter would not have sufficed to allow the workmen time to escape in the highly inclined working places where they occurred, and as the speed of exit depends materially upon the possession of good lighting. The logical remedy, according to Audibert and Delmas, is to use a fire damp indicator or flame safety lamp in conjunction with the electric lamps. It is essential, however, that the workmen should be capable of reading the warnings given by such appliances and of acting upon them without a moment's delay. In England much the same view is held; the defect of the system advocated is that the flame lamp is too often neglected when it is not used as a means of illumination. The matter is largely a question of training and discipline, and to this fact may be attributed the immunity from this class of accident in Germany. The danger, it may be added, is still more pronounced in any system of lighting from the mains, owing to the greater liability that the whole of the lights may be extinguished. The use of electric lamps, Audibert and Delmas consider, may tend to increase the prevalence of accidents of the second type referred to, and one case is mentioned where the workman had actually left his flame lamp behind before entering the old workings, presumably because he suspected that it would be extinguished! The best remedy against such foolishness is to render access to such places impossible. Such measures the authors regard as a necessary corollary to the generalized use of electric lamps. The third type of accident is that which appears a priori to be most likely to increase with the suppression of flame lamps, yet of the nine accidents dealt with there was one only in which the workman did not carry a flame lamp; in the others the victims had neglected to test for gas or had ignored the indications; when both kinds of lamp were in use, extinction of the flame was disregarded. This also points to the need for greater discipline and the cultivation of a better respect for danger; but it is necessary also to blame the management, which is responsible for the defective ventilation.

Canada.- According to Nicholson[53] a dashboard dial has been devised that indicates the percentage of carbon monoxide in the exhaust gas of automobiles. He discusses the device as follows:

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[53] - Nicholson, D., Carbon Monoxide Poisoning: Canadian Pub. Health Jour., vol. 22, No. 12, Dec., 1931, p. 606.

> It depends on the fact that the electric resistance of platinum wires increases as they become heated, and this shunts the current through a meter which indicates the amount of carbon monoxide pouring out of the exhaust. The platinum is specially treated to act in the same manner as the sponge platinum used for the type of gas lighter which begins to glow when held over a gas jet. There is a pipe lighter which works on the same principle. Let us hope that this device will be perfected in the near future and become standard equipment on all cars. It will not abolish monoxide from the exhaust gas but it is a splendid warning. There is another reason why this meter will attract much attention. It tells the percentage of fuel wasted and so will make for economy by enabling the operator to cut down on mixtures that are too rich.

The effects on health of smoke and fumes in the atmosphere in and around industrial centers continues to claim the attention of public health officers, as well as the general public affected.

Belgium.- A number of conjectures have been made in regard to the cause of the catastrophe that occurred in the Valley of the Meuse in December, 1930, when hundreds of persons became ill and 63 died. Van Leeuwen[54] gives the following description of this untoward event:

> On December 1, a Monday, a fog developed in Belgium and in the Netherlands. In the valley of the Meuse the fog was especially heavy, and on account of an absolute calm it did not lift until Thursday afternoon. On Friday it again became foggy and it remained so until Sunday. On Tuesday and Wednesday the fog was especially heavy. On Wednesday a large number of persons complained of irritations in the nose, mouth, throat, trachea and bronchi. The mucous membranes were red and swollen. Necropsies later revealed that the inflammation reached down into the large ramifications of the bronchi. The patients coughed and the respiration frequency was more than 40 a minute. In the serious cases dyspnea, dilatation of the heart, high pulse frequency and cyanosis developed. Signs of pneumonia were not present. Injections of epinephrine brought temporary improvement, and cardiac stimulants were also administered. Among those who were seriously ill, and especially among those who died, there were many old persons, also persons with asthma, bronchitis and heart disease. However, it was also noted that young persons who had been healthy before became seriously ill and that many others felt an unpleasant irritation in the throat. The 63 fatalities all occurred within 24 hours and in the narrow valley south of Liege. In discussing the causes of the catastrophe the author points out that the opinion that the heavy, cold fog is irrespirable and that the fatalities were due to suffocation from lack of oxygen is not tenable because heavy, cold fogs are quite frequent on the sea coast of the Netherlands, and yet there are no fatalities. The theories of war gases and of Sahara

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54 - van Leeuwen, Storm, Fog Catastrophe in Industrial Section South of Liege: Jour. Am. Med. Assoc., vol. 96, No. 16, April 18, 1931, p. 1347.

sands are likewise dismissed. In traveling through this region the author noted numerous factories such as zinc industries, superphosphate factories and other industrial plants. It may be assumed that even under normal conditions the air contains irritative substances such as sulphur dioxide and hydrofluoric acid. It is also known that this region is fit for neither agriculture nor cattle raising. That this is due to the presence of the factories is proved by the fact that the cattle raisers had a lawsuit against the manufacturers and were paid damages. The cold and heavy fog and the absolute calmness during the first days of December prevented ventilation, and it is also possible that some of the factories discharged an abnormally large amount of poisonous substances during these days. This catastrophe teaches that the harmfulness of gases discharged by certain industries should not be estimated on an ordinary day but on the concentrating effects of fogs should be taken into consideration.

England.- Des Voeux, president of the National Smoke Abatement Society, in his annual address[55] said that excessive smoke was not a necessity, but a luxury of laziness, which should not be allowed by authorities charged with the protection of the health of the people. The local authorities were working in conjunction with the Department of Scientific and Industrial Research, which was investigating the impurities of the atmosphere. In a square mile of the city of London, 150 tons of dirt fell in 1911, while in 1930 the figure was 380 tons. Similar figures were obtainable from other large centers. The destructive elements in the combustion of coal was now known to be sulphur dioxide, which was turned into sulphuric acid in the air. The report on the disastrous fogs in the Meuse Valley last winter stated definitely that the deaths were due to suffocation, which might easily be reproduced in closely inhabited neighborhoods had not the Government been forewarned in time to insist that measures be taken to prevent the escape of this gas into the air, or to neutralize it before it escaped. At the new electric station being erected at Battersea (in London) the enormous amount of 2,000 tons of coal would be burned daily, emitting, at the smallest calculation, 30 tons of sulphur, which is equivalent to 90 tons of sulphuric acid. Imagine the effect of this acid, if it should accumulate for four or five days, as it well might, on the unfortunate population of closely packed Battersea. But in speaking of factory smoke, Des Voeux did not minimize the effect of the domestic chimney, especially the kitchen range. However, the domestic chimney could not be abolished until smokeless fuel could be produced at the price that the poor could afford.

A report was presented by the Greater London Joint Smoke Abatement Committee, regretting that no satisfactory method of measuring the density of smoke had yet been evolved. The subject was still receiving the attention of the Government fuel research station. Great progress had been made in London in connection with the control of smoke emission. Beneficial effects were being secured under the law which prohibited the emission of black smoke for more than three minutes in 30, but the committee was still not satisfied and regarded a 2-minute period as necessary, which it hoped would be in force in 1936.

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[55] - des Voeux, H. A., Air Pollution by Smoke, (Foreign letter): Jour. Am. Med. Assoc., vol. 97, No. 18, Oct. 31, 1931, p. 1313.

The Department of Scientific and Industrial Research,[56] which is responsible for the investigation of atmospheric pollution, has exhibited at its conference with the local authorities, who collaborate with it, some new devices for measuring air pollution. The apparatus commonly used is the standard deposit gage. Material deposited from the air into the funnel of the gage is washed by rain into a bottle beneath, and at the end of every month the contents are analyzed. The method gives some idea of the amount of sulphuric acid in the atmosphere, the most destructive element of air pollution, but it does not provide an estimate from day to day. This can now be gained from an apparatus developed by the Government chemist, which will be used to determine whether a great new power station in course of erection in London is emitting sulphur fumes. The air to be examined is pumped through a glass tube containing a chemical that absorbs sulphur dioxide and fixes it as sulphuric acid. Several local authorities have adopted an automatic air filter devised by J. S. Owns, the superintendent of observations, to measure the amount of suspended impurity in the air. A standard volume of air is passed through filter paper, forming on it a dark spot of varying blackness according to the amount of impurity. By a clockwork arrangement, records corresponding to each hour of the day are obtained; the degree of blackness of each series of spots is afterward measured by comparison with a standardized scale of shades numbered from 1 to 20.

Another new apparatus is for measuring daylight. The light passes through an optical wedge, in contact with which is a metal plate perforated with small holes in a line. The light transmitted through these holes varies in intensity from one end of the line to the other. By means of a split lens, two images of the holes are formed on photographic paper, and by light filters the radiation forming one image is confined to the ultraviolet region, the radiation forming the other to a portion of the visible spectrum. The photographic record for the day, therefore, consists of two parallel rows of dots, each diminishing in shade along the row. By noting the last hole visible in each line, an arbitrary measure of the relative average intensity of the two kinds of radiation is obtained and the variations in the total amount of daylight from day to day can be estimated. Seven such records can be taken, one for each day of the week, before the sheet of photographic paper is changed and the clockwork rewound.

The Lancet[57] mentions the case of a man who, after becoming apparently perfectly acclimatized to a low partial pressure of oxygen, had his chest movements restricted by a bruising of the thorax. As a result he suffered from anoxaemia and developed symptoms usually associated with a sudden reduction of the partial pressure of oxygen in an unacclimatized person. The margin of safety is low. Pneumonia at high altitudes is for the same reason rapidly fatal, the condition of the patient being similar to that of a pneumonic patient at low altitudes whose oxygen demands are suddenly increased by movement.

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[56] Journal of American Medical Association, Foreign Letters, London: Vol. 96, No. 23, June 6, 1931, p. 1963.

[57] The Lancet, vol. 11, No. 43, London, Sept. 26, 1931, p. 683.

Greene,[58] in an attempt to sum up the present position in regard to the use of oxygen in climbing Mt. Everest, states that the recent success of the British Himalayan Expedition in climbing, without the use of oxygen, 10 of the greater Himalayan peaks, including Kamet (25,447 feet), the highest summit yet attained, has brought once more into prominence the question of the use of oxygen on Everest. It is a question on which both climbers and physiologists are divided.'

> The problem to be solved is whether or not oxygen can be regarded as a helpful factor in high climbing. One school of thought claims that, in the face of theoretical considerations and practical experience, it is impossible to deny its usefulness. The special difficulties of Everest are due chiefly not to terrain or climate but the want of oxygen. To supply this want can scarcely fail to reduce the difficulties of the ascent. Moreover, Prof. J. Barcroft has shown by direct experiment that, under laboratory conditions, it is possible to do by means of oxygen what is certainly impossible without it--to climb at a rate of a thousand feet an hour, without previous acclimatisation, at a barometric pressure equal to that of the summit of Everest. Much practical experience points in the same direction.
>
> The no-oxygen school claims, on the other hand, that the conclusions are unsound because, both in the Barcroft steel chamber experiment and on Everest, the 'subjects' were either unacclimatised or only partially acclimatised. Acclimatisation appears to occur in three different ways. In the well-trained person, oxygen secretion by the lung epithelium increases the oxygen supply to the blood at a very early stage of an ascent. The existence of oxygen secretion is denied by some physiologists. In this battle of the giants I do not propose to take a part. It does not affect our main issue, because it does not occur to a sufficient extent to affect the question of whether or not oxygen should be carried on Everest. A great increase in the haemoglobin percentage of the blood undoubtedly occurs, but this increase will not make possible the continuance of life at very great altitudes, unless supported by an actual increase in the pressure of oxygen in the lung alveoli. This increase is attained by deep breathing.

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[58] Greene, Raymond, Oxygen and Everest: Nature, vol. 128, Nov. 28, 1931, pp. 893-894.

If, then, the oxygen school believes in the usefulness of oxygen for high climbers, whether acclimatised or not, and the no-oxygen school believes in its usefulness for the unacclimatised, a method of attack in conformity with both points of view appears at first sight to be obvious. It should be possible to eliminate the necessity for acclimatisation by using oxygen from a low level on the mountain and climbing it at alpine speed. But here two great problems present themselves. It is very difficult to construct an apparatus which will without waste deliver the required quantity of oxygen while the climber is eating and sleeping; and it is impossible at the moment to find an apparatus which can be trusted never to go wrong. The failure of his oxygen apparatus near the top of Everest would mean death to the unacclimatised mountaineer.

The other extreme view has also been presented, but never by anyone with experience of Himalayan climbing--the view that Everest should be attacked by a party prepared, if necessary, to spend a year upon the mountain. To rush a mountain is folly, unsound in theory and disastrous in practice. Siege tactics have been proved sound. But there must be moderation even in slowness. The weather of the great peaks allows only a limited time in which to make the ascent, and many months upon a mountain undermine the health of the climbing party. It is possible that before sufficient acclimatisation for an oxygenless assault on the summit of Everest has been attained, altitude deterioration may have set in. If by relying on oxygen for the last few thousand feet of Everest it is possible to reduce the time on the mountain and thus the danger of deterioration, the chances of a successful attempt will be increased. Whether this can be done will be determined by direct experiment in a steel decompression chamber.

The practical difficulties of oxygen are serious. The apparatus in use in 1924 was so heavy that, in the opinion of some, its weight outbalanced its advantages. Valves tend to freeze or leak, and complicated taps are difficult to work under trying conditions. Many improvements have been made in the last five years, but there is room for more. There should be produced a light, simple, and efficient apparatus, thoroughly tested in refrigerators and mid-tunnels and on the mountains of Europe. This task has been undertaken by a committee of the British Association. If such an apparatus can be designed it should, as soon as permission can be obtained, be placed in the hands of a young, well-drilled, and well-organised party. Such a party will, in my opinion, climb Everest. It will at any rate show us whether or not oxygen can be of service to the unacclimatised man.

The investigations by Bancroft mentioned above were made in a steel chamber[59] wherein the barometric pressure was reduced to that at the top of Everest (11 inches of mercury). In the chamber, the exertions necessary for climbing 1,000 feet an hour were made by stepping on and off a block of wood 13 inches high. Although an ordinary person would faint in air at such low pressure, it was found that "the climb" could be done just as easily as outside at ordinary atmospheric pressure. Given the necessary oxygen, the drop of barometric pressure had no effect. Against this advantage there would be in mountain climbing such difficulties as the weight of the apparatus and the effect of frost on the valves and tubes.

In an article on the effect of carbon monoxide on small birds, Killick[60] mentions the following questions requiring investigation:

> (1) What is the lowest atmospheric concentration of carbon monoxide that will cause unmistakable symptoms in a bird? (2) Is this concentration sufficiently low to be harmless to man? (3) What conditions modify the reaction of the bird to carbon monoxide?
>
> To take these questions in order - as regards the first, a certain number of data have been collected by workers connected with the United States Bureau of Mines showing that a fresh canary will show unmistakable signs of distress when exposed to an atmosphere containing 0.16 per cent of carbon monoxide or more; possibly this figure should be put a little lower. The next question is, are concentrations of carbon monoxide below 0.16 per cent harmless to man? According to Haldane, in experiments performed upon himself, a percentage saturation of 35 to 40 in the blood is reached in an atmosphere containing 0.12 per cent carbon monoxide in two hours; in an atmosphere containing 0.21 per cent carbon monoxide in 45 min.; in an atmosphere containing 0.36 per cent carbon monoxide in 30 min. It appears, therefore, that canaries do not supply a perfectly safe indication of dangerous quantities of carbon monoxide, when these quantities are near the lower limit of danger.
>
> It has been noticed in experiments with canaries that birds show very considerable individual variation in their reaction to carbon monoxide; this variation becomes greater in degree with smaller quantities of carbon monoxide in the atmosphere breathed. In the first series of experiments all the birds were being exposed for the first time, and it is the birds exposed to 0.12 per cent carbon monoxide that show the biggest range of individual variation, while those exposed to 0.26 per cent carbon monoxide

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[59] Journal of American Medical Association, Oxygen in Mountain Climbing: Vol. 97, No. 17, Oct. 24, 1931, p. 1236.

[60] Killick, E. M., Effect of Carbon Monoxide on Small Birds: Colliery Guardian, March 6, 1931, p. 850.

show the smallest range. This question of individual variations is closely connected with that of adaptation to carbon monoxide. It is of considerable practical interest to ascertain whether the birds used to detect the presence of carbon monoxide undergo a process of adaptation similar to men, and a series of experiments was undertaken to throw light on this point. In every case, as a result of successive daily exposures to carbon monoxide the sensitivity of the birds to a test exposure progressively decreased. There is one exception to this, where at the end of one experiment the sensitivity increased again. There have been indications of this late result in other experiments, but the data are at present insufficient to warrant a discussion of its significance. Amongst the birds that did show distress, the time interval became greater with successive exposures. In one case, when exposed to 0.16 per cent carbon monoxide, the birds ceased to show definite signs of distress after the ninth day; in the case of daily exposures to 0.12 per cent carbon monoxide, none of the birds showed distress after the eighth day. In another experiment where the birds were exposed daily to 0.22 per cent carbon monoxide, signs of distress persisted even after 20 exposures, but the time interval before falling from the perch had increased to that of a fresh bird exposed to 0.16 per cent carbon monoxide. This is in agreement with the statement made by Royd Sayers that a canary with an acquired tolerance of carbon monoxide can stand twice the concentration of a bird not previously exposed. Comparing these results with the symptoms observed in man on exposure to the same atmospheric concentrations of carbon monoxide, we find that in an atmosphere containing 0.22 per cent carbon monoxide, a bird, whether acclimatised to carbon monoxide or not, will fall from its perch within 12 min., whereas the danger point for a man at rest is not reached in less than 40 min. This gives a moderate margin of safety, so that we may say a bird is reliable as a warning in atmospheres containing more than 0.22 per cent carbon monoxide. Below this atmospheric concentration, however, the reliability of the bird depends on its previous history and on individual idiosyncrasy. In 0.16 per cent carbon monoxide a fresh bird will fall within 23 min., whereas the danger point for a man at rest is not reached for about 1¼ hours, but a bird with an acquired tolerance to carbon monoxide may not fall at all in this atmospheric concentration of carbon monoxide. With an atmospheric concentration of 0.12 per cent carbon monoxide or below, a fresh bird may not fall from its perch, although the danger point for a man at rest may be reached in two hours.

United States.- According to Hoffman,[61] from 1921 to 1924 there were 8,719 deaths (2.29 per 100,000 fatal accidents in the United States registration area) from absorption of irrespirable, irritating, or poisonous gas; in 1925 to 1929, the number of deaths was 13,003 (2.32 per 100,000); and for the period 1921-1929, the number of deaths from this cause was 21,722 (2.31 per 100,000).

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[61] Hoffman, F. L., The Fatal Accident Problem in the U. S.: The Spectator, Jan. 14, 1932.

According to the Ohio Health News[62] deaths still occur from carbon monoxide from various sources. The following is a summary of the cases in Ohio:

> A summation of the carbon monoxide mishaps associated with gas-fired heating appliances, reported to the Division of Industrial Hygiene, State Department of Health, for the year July 1, 1930, to June 30, 1931, shows that there was a considerable reduction in the number of fatalities from those of preceding years. In the year 1929-30 there were 52 deaths. The average for the last five years is 44. This year there are 29 deaths, including three from unburned gas, two of which were suicides. In addition, there are newspaper clippings (only) of nine additional cases with three deaths, not included in the above figures.
>
> As to location and type of appliance involved, these cases were pretty well scattered. Space-heaters were associated with 12 deaths, water heaters with 5, gas ranges with 6, and hot-plates with 3 deaths. Twenty-six cases with 6 deaths occurred in bedrooms, 14 cases with 8 deaths in living rooms, 16 cases with 5 deaths in bathrooms, and 21 cases with 5 deaths in kitchens. Heaters in bedrooms and water heaters in bathrooms continue to be among the leading offenders.
>
> The cause or causes of the reduction in the number of deaths this year can only be surmised. Are the people becoming aware of the dangers of faulty or maladjusted gas stoves? Is the publicity given this danger by health officials and newspapers for the past few years having an effect? Whatever the cause, it is to be hoped that the number of deaths will continue to be low and to become lower in the succeeding years.
>
> A faulty water heater in a school basement was the cause of 13 cases, although there was no death. Four cases were reported due to gasoline water heaters and clothes press, with no deaths.
>
> Reports of mishaps from auto exhaust are not so encouraging as those given above. This year there is a considerable increase in the number of deaths from this source. Out of a total of 98 mishaps there were 41 deaths. Last year there were 35 deaths out of 84 cases due to exhaust fumes. All deaths occurred in garages. Five apparently were suicides.

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[62] Ohio Health News, Death Still in the Fumes: Vol. 7, No. 18, Sept. 15, 1931, pp. 3-4.

The number of carbon monoxide mishap reports received by the Ohio Department of Health[63] for the first six months of the year 1931-32 has taken a great tumble from the height maintained in previous years. From July 1 to Dec. 31, only 14 reported cases, 7 of which were fatal, were associated with gas-fired heating appliances; 3 of these evidently were suicidal, due to unburned gas, according to records kept by the departmental division of industrial hygiene.

The following table shows the comparative record of cases and deaths reported since 1925:

	Cases	Deaths
1925-26	100	57
1926-27	122	43
1927-28	136	38
1928-29	168	36
1929-30	123	52
1930-31	123	29
1931-32 (1st 6 mos.)	14	7

The above information would seem to indicate that the publicity given this danger by health officials and newspapers for a number of years past is at last having its effect, although the influence of an unusually mild winter can not be disregarded in this year's total. Whatever the cause of the present decline, it is to be hoped that it will continue in succeeding years.

Carbon monoxide is just as poisonous as ever, and in case of carelessness or accident will cause death just as quickly. Vigilance and watchfulness in the proper installation and operation of gas appliances are necessary in order to prevent such mishaps.

Statistics on auto exhaust mishaps for the last six months are not quite so favorable. Here there are 20 cases, 13 of them fatal. The majority of these occurred in closed garages. One fatality occurred while the person was greasing an automobile in a service station. Another man died when fumes were forced up through the car while stranded in a stream of water. One nonfatal case occurred in an automobile salesroom and another in a feed-grinding establishment.

Death by carbon monoxide is considered a compensable accident in Ohio. The death of a workman in a mine from the inhalation of carbon monoxide in the course of his employment was, in the opinion of the court of appeals of Ohio, Carroll County, due to an "accidental injury," within the meaning of the Ohio compensation act, and not to an occupational disease.[64]

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[63] Ohio Health News, Carbon Monoxide Poisoning: Vol. 8, Jan. 15, 1932, p. 2.

[64] Journal of the American Medical Association, Medicolegal: Vol. 97, Dec. 26, 1931, p. 1986.

In New York[65] in 1930, there were 142 fatal accidents from irrespirable or poison gas, 17 of which were public, 105 in the home, 15 industrial, and 5 unknown.

Violations of the smoke ordinance in New York City have been reduced more than 85 per cent during the past year through the efforts of the Health Department, according to Thomas Darlington,[66] head of the trial board for offenders. While the board heard an average of 70 to 80 cases weekly when the smoke abatement work started a year ago, only 8 to 10 cases are now brought each week, he stated.

Most offenders, Darlington said, have not known that they were making smoke and have taken corrective steps after being apprised of their offense.

On the other hand, Darlington explained, it has been found difficult to prove to the courts that smoke from chimneys constituted a health menace. He said he had been informed that in one or two of the cases lost in court, the lawyers' fees for the defense have been far more than the cost of correcting the smoke nuisance.

Darlington held that lack of education as to the harmfulness of smoke was mainly responsible for the nuisance. A survey of the city from tall buildings, he said, would show that at present the air is free, except from the smoke coming from power houses and heating plants, since the private owner has brought about more improvements.

For a long time the problem of carbon monoxide, arising from the contamination of city and garage air by automobile exhaust gas, has been of intense interest, not only to the medical profession, but to the public. The traffic congestion at busy corners in large cities has so increased in recent years that atmospheric pollution by the exhaust gases of automobiles has become an acute health problem. In the past, this problem has not been investigated searchingly, and comparatively little information, which deals directly with the menace from gases from automobile exhausts in traffic, is available. Several years ago, the United States Public Health Service, after a brief survey in a number of American cities, suggested that carbon monoxide is a potential hazard to policemen on long duty at congested city corners. Since then traffic has increased in volume and other changes have occurred, such as in automotive fuels, and these conditions in themselves warrant a thorough-going research.

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[65] The Military Surgeon, Fatal Accidents in New York State: Vol. 69, No. 5, 1931, pp. 556-557.

[66] Darlington, Thomas, Smoke Violations Reduced 85 Per Cent in New York: Power, vol. 74, No. 19, Nov. 19, 1931, p. 691.

The director of the Department of Public Health, of Pittsburgh, Pa., with a group of collaborating specialists, decided to carry out broad studies of the amounts and effects of carbon monoxide in the air and of certain other health hazards arising from street traffic, and especially from air pollution by automobile exhaust gas, at busy corners in Pittsburgh.[67] The investigation was initiated at conferences held in May, at which there was secured the active cooperation of the Mellon Institute of Industrial Research, the University of Pittsburgh, the United States Bureau of Mines, the city's Department of Public Safety, and the Better Traffic Committee. Data are being secured at busy downtown street corners, and it is expected that the whole survey will require a year.

At each station, continuous records of the amounts of carbon monoxide emitted into the air by automotive vehicles during all hours of the day are obtained. In the apparatus used, the carbon monoxide is determined automatically by an ingenious method devised at the Pittsburgh station of the United States Bureau of Mines. Simultaneous and continuous traffic observations are made at each station in order to ascertain the influence of traffic congestion, traffic disturbances, types of vehicles, and modified automobile exhaust emission upon the prevalence and quantity of carbon monoxide, hydrocarbon vapor, and dust. Later on, the effects of excessive traffic noise will be accorded study.

The apparatus, in charge of officials of the Bureau of Mines and the Mellon Institute, is now installed at the third station to be investigated. Determinations are proceeding satisfactorily, and continuous, 24-hour records are being kept by automatic recorders on the chemical robot that the Bureau of Mines invented and developed. Progress reports will be published from time to time as definite conclusions can be deduced.

This investigation, the first of its kind, will be sufficiently comprehensive to give results on which recommendations may be made respecting the lengths of time, at different periods of the day, that traffic officers can safely be on duty, with proper regard for their health, at the principal corners throughout the city. It will also lead to valuable information concerning the effects of exposure to very small amounts of carbon monoxide over protracted periods.

At present, owing to a dearth of reliable data, medical specialists are uncertain about the action of traces of the gas on human beings, when the latter inhale such minute amounts regularly, several hours a day, year in and year out, on streets and in bordering buildings. It is known that carbon monoxide is an extremely fugacious and diffusible gas that quickly leaves its source, ascending to levels above the street. The investigators will try also to learn about the carbon monoxide producing effects of different types of cars, of various ways of operation, and of changes in mufflers.

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[67] Pittsburgh's Health, Air Pollution by Carbon Monoxide: Vol. 2, No. 18, Sept., 1931, pp. 66-67.

The following statement has been made by Newell[68] in regard to poisoning by natural gas:

> Natural gas as it comes from the wells in Oklahoma is made up of a mixture of methane, CH_4, and ethane, C_2H_6. These are gases at ordinary temperatures. Hydrocarbons of a higher weight than this are liquids or solids at ordinary temperatures. Gasoline and kerosene are the lighter forms next to natural gas. Some of the gas, however, is very heavy in gasoline, of which ethane is a principal part, and the symptoms of gasoline vapor poisoning seem to dominate in natural gas poisoning. Methane itself seems to be a rather inert gas with no odor. Its presence has been demonstrated in old wells and mines by the extinguishing of a lamp. There is little effect produced by methane other than a deficiency of oxygen. Ethane or gasoline fumes, however, produce the toxic results.
>
> It has been found that breathing from 10 to 15 gm. of gasoline in eight minutes causes dizziness, nausea and drowsiness. Inhaling from 30 to 40 gm. in ten to 12 minutes produces anesthesia. Tested on dogs, it was found that breathing a dilution of 85 parts to 10,000 of air caused drowsiness, and if the concentration was increased to 156 parts the animal would fall. Recovery followed when removed at this moment after a few clonic spasms. A dilution of 192 parts caused the dog to lose consciousness and recovery followed after several convulsions. One dog died when a concentration of 243 parts to 10,000 was reached.
>
> Men sent into tank cars without the proper protection often exhibit symptoms of mild mania, and refuse to leave the tank. They shout, sing, and often lose consciousness before they can be forced out. They seem to lose their reasoning power. Their pulse is rapid, then slow, temperature falls and skin becomes cyanotic. Some die from the exposure, in spite of the fact that oxygen may have been supplied at the same time they received the gas fumes.
>
> From the Bureau of Mines we have a statement that they have found a 2½ per cent gasoline vapor with a high per cent of oxygen that would make one dizzy, and soon become intolerable.
>
> Natural gas is piped into our homes under a pressure of from 4 to 6 ounces. Users are very careless in connecting these pipes to their fixtures and leaks are often the result. Breathing this gas has the same effect on the economy as the fumes of gasoline. At first there is a little dizziness, and possibly a headache. Next a feeling of numbness and analgesia, followed by anesthesia, and unless removed from the atmosphere of the gas, convulsions, unconsciousness and death follow.

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[68] Newell, W. B., Poisoning from Natural Gas and Its Combustion Products: Internat. Med. Digest, Hagerstown, Md., vol. 19, Dec., 1931, pp. 327-328.

> Recovery is prompt when patient is removed, but headache and a wretched feeling follow, and continue for one or two days. In severe or prolonged gassing, various late nervous effects are reported, such as weakness of the legs, vertigo, nystagmus and tremors.

The chemical and pathological reaction of dogs to asphyxia by carbon monoxide and by atmospheres which are deficient in oxygen has been studied during the past two years by the United States Bureau of Mines.[69] These studies have been conducted for the purpose of obtaining fundamental information on the response of the organism to asphyxial environment, with the particular object of devising a procedure for treating moribund cases of carbon-monoxide poisoning. It has been repeatedly observed that many of these cases have a fatal termination, even though respiration has been induced and the carbon monoxide removed from the blood.

The results of the first of the series of these studies, on neuropathology resulting from asphyxia, are summarized by the authors as follows:

> The neuropathology produced in dogs by fatal exposures of 20 to 30 minutes to 0.6 per cent carbon monoxide in air by volume was studied.
>
> The brain, as a whole, showed a severe perivascular and perineuronal edema. This was most marked in the corpus striatum, the cortex, and the dorsal motor nucleus of the vagus nerve. The vessels were greatly dilated and tightly packed with red blood cells. Stasis was marked throughout. There were a few petechial hemorrhages, especially in the corpus striatum and cortex. Most of these were not larger than would occur by diapedesis through the dilated vessels. Occasionally a few leucocytes, both lymphocytes and polymorphonuclear leucocytes, were found in the perivascular spaces. The endothelium of the capillaries appeared to be swollen in some areas.
>
> The neurons were extensively damaged. Many of the nerve cells seem to have been ruptured. In some areas all that appeared to be left of the nerve cell was a swollen, distorted, and vacuolated nucleus with a little Nissl material around it. A clear space marked the site of the original cytoplasm of the neuron. In others there was a marked central chromatolysis with distorted nuclei. This was most pronounced in the cells of the nuclei pontis. The Nissl material was dust-like in some of the very large cells, as in some of the neurons of the nucleus ruber. In others the Nissl granules were abnormally large and decreased in number. Some of the cells, especially the small pyramidal cells in the cortex and the cells of the dorsal nucleus of the vagus, were shrunken and stained homogeneously a dark blue. The nuclei were swollen, distorted in shape,

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[69] Chornyak, John, and Sayers, R. R., Studies in Asphyxia. I. Neuropathology Resulting from Comparatively Rapid Carbon-Monoxide Asphyxia: Pub. Health Repts., vol. 46, No. 26, June 26, 1931, pp. 1523-1530.

and frequently eccentric. They contained very little chromatin material. Many of the nerve cells were shrunken.

Many of the large polygonal-shaped cells containing well-developed Nissl granules, located throughout the reticular formation of the brain stem, showed practically no change. Likewise, the nuclei of the hypoglossal, abducens, trochlear, oculomotor nuclei, and nucleus ruber showed relatively little damage. The dorsal motor nucleus of the vagus nerve, dorsal sensory areas of the brain stem, the corpus striatum, and the cortex showed severe injury.

There was a variation in the degree of damage with different animals. With three of the four dogs studied the variation was not marked, but the fourth showed distinctly less damage. The foregoing findings were, however, present to some degree in all of the animals.

The following conclusions may be drawn:

1. The circulatory changes are characterized by dilatation, stasis, perivascular hemorrhage, and edema.

2. Edema is diffuse and severe. It is both perineuronal and perivascular.

3. There is a marked difference in the susceptibility of the nerve cells to oxygen deprivation. The cells of the cortex, corpus striatum, dorsal motor nucleus of the vagus, and the dorsal sensory areas of the medulla, are the most sensitive. The nucleus ruber, nuclei of the oculomotor, trochlear, abducens, and facial nerve, and the large polygonal cells in the reticular formation of the medulla are the least susceptible.

4. There are two general types of degenerative changes in the nerve cells following asphyxia: (a) Some become shrunken and stain diffusely; (b) others show varying degrees of chromatolysis.

5. Carbon monoxide produces a diffuse degenerative change throughout the entire brain.

6. In this type of asphyxia the most serious effect appears to be edema of the dorsal motor nucleus of the vagus and the adjacent area in the medulla oblongata.

The following is the summary[70] of the second series of the investigation which dealt with the blood chemical changes resulting from comparatively rapid asphyxia by atmospheres deficient in oxygen:

> A study was made of blood chemistry changes in dogs exposed to atmospheres which were depleted of oxygen at a rate which caused a progressive asphyxial condition simulating asphyxia resulting from exposure to approximately 0.6 per cent carbon monoxide in air by volume. The conditions caused death in 11 to 18.5 minutes. The study was made not only to ascertain the changes attending asphyxia by insufficient atmospheric oxygen, but also as a parallel to a similar study of the changes attending asphyxia by carbon monoxide in order to ascertain if there were changes which were peculiar to each type of asphyxia or if they were identical and due entirely to anoxemia.
>
> 1. There was a marked hyperglycemia and hyperuricemia; the non-protein nitrogen and urea increased slightly; the total and preformed creatinine remained practically normal; and the inorganic phosphorus increased.
>
> 2. There was an increase in the hydrogen ion concentration and a marked decrease in the carbon dioxide capacity of the plasma, and the carbon dioxide content of the blood.
>
> 3. The oxygen saturation of the arterial blood at death ranged from 1.3 to 8 per cent.
>
> 4. The red blood cells increased in one case, but showed no significant change in two. The white blood cells and polymorphonuclears increased while the lymphocytes decreased.

Barcroft and Margaria[71] have experimentally investigated the effect of CO_2 inhalation upon human respiration. They find that the rates of both inspiration and expiration are quickened, and that the time taken by each phase is shortened. The rate of inhalation of air at the middle of inspiration varies almost exactly with the total ventilation. These variations were found by the authors to be the same for a person, whether the hyperpnoea was produced by CO_2 inhalation or by exercise. The maximum total ventilation produced by exercise was nearly twice as great as that produced by the highest concentration of CO_2 which could be breathed for a quarter of an hour. The authors conclude, therefore, that CO_2 inhalation and exercise act in a similar way, but that the maximal effect of the first falls short of that of exercise. The breathing of 7.5 per cent of CO_2 for 20 minutes produces a shock from which the system does not wholly recover for some hours. It seems clear that carbon dioxide can only be one contributory factor in the production of dyspnoea by exercise.

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[70] Schrenk, H. H., Patty, F. A., and Yant, W. P., Studies in Asphyxia. II. Blood Chemistry Changes Resulting from Comparatively Rapid Asphyxia by Atmospheres Deficient in Oxygen: Pub. Health Repts., vol. 47, No. 3, Jan. 15, 1932, pp. 136-146.

[71] Barcroft, J., and Margaria, R., Pathology. Effect of Carbon Dioxide on Respiration: British Med. Jour., No. 3688, Sept. 12, 1931, p. 42.

According to Heating Piping and Air Conditioning,[72] in the light of our meager knowledge of the effects of atmospheric pollution on health, it is fair to say that any conspicuous air pollution constitutes a liability to property and health, and that steps should be taken to reduce the pollution to a minimum. This would require the concerted efforts of the fuel engineer, the public health officer, and the public itself.

SUMMARY OF RECENT LITERATURE ON ABNORMAL TEMPERATURES AND HUMIDITIES

Australia.- Attention was recently drawn to the occurrence of boils and carbuncles among miners by the number of men at a certain colliery who were afflicted with them.[73] Inquiries at this mine made evident various factors, any of which might have been the cause of the cases found. Of these factors, three were outstanding: (a) The temperature at the working face--dry bulb, 90°F, wet bulb 80°F; (b) the hardness of the drinking water; and (c) the fact that most of those suffering from boils were men who had been off work for terms up to two years and who were newcomers to the district. In order to determine more exactly which of these factors was the material one, 20 other collieries were visited and information was received from 20 more. About 200 men were examined or interviewed. The investigation at the various collieries resolved itself into two parts--namely, examination of the men and examination of conditions at the mine. The depths of the mines visited ranged from 300 to over 1,000 yards, and the distances inby to the working places up to 2½ miles. The highest temperature met with at the face was 93°F. dry bulb and 85°F. wet bulb; the lowest was 53° dry and wet bulb. In mines where the wet bulb temperature was about 75° or over, the men worked partially stripped--that is, in shorts and boots--and the occurrence of boils was most noticeable in mines where the temperature at the face reached or passed 75°F. It was observed, too, that boils occurred more often on men who sweated profusely and whose bodies were covered with a fine film of wet coal-dust--as one may put it, "the body is as if covered with boot polish."

It was concluded that, as far as mines are concerned, boils do not present a serious problem, except in a few isolated cases, and that the main factor in the causation of boils underground (apart from the predisposition to them of the individual--e.g., malnutrition, seborrhea, etc.) is a high wet-bulb temperature (75° and over) which at one and the same time indicates suitable conditions (warmth and moisture) for the vitality of the organism, and opens the sweat glands and hair follicles and thus facilitates the entry of the staphylococcus.

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[72] Heating, Piping and Air Conditioning, Atmospheric Pollution: Nov., 1931, p. 932.

[73] Fisher, S. W., Boils and Carbuncles Among Miners: Queensland Govt. Min. Jour., vol. 32, Sept., 1931, p. 368.

The treatment recommended was the use of manganese injections and treatment of the local lesion by painting it with contracile collodion. To the managers of mines where boils occur, it was suggested that every effort should be made to improve the ventilation, lower the temperature, and minimize wetness. The men were advised to apply an antiseptic, preferably tincture of iodine, to the smallest scratch, cut, or boil as soon as possible and to avoid touching the boil with the fingers, to drink as little water as possible, and preferably water with a small amount of salt added to it (about 10 grams to the gallon), and whenever available to make full use of pithead baths.

England.- The following report[74] is made of an investigation carried out in 1927-1928 on the relationship of absenteeism to the atmospheric conditions experienced underground in the 10 collieries described in the previous report for the years 1924-1925:

> The present results relate to the men working in 13 different localities, and the results obtained in the two statistical periods correspond fairly well in most of the localities, but in order to demonstrate clearly the relationship of accidents to temperature it is necessary to re-classify the data in temperature groups. At dry-bulb temperatures of less than 70° the coal-face workers suffered 133 accidents in 1927-28, as against 104 in 1924-25. At temperatures of 70° to 79° the frequency experienced in the two periods was exactly the same, but at temperatures of 80° and upwards it was 173 in 1927-28, as against 184 in 1924-25. That is to say, in both statistical periods a rise of temperature was associated with a rise of accident frequency, but the rate of rise was not half as great in the later period as in the earlier one. The severity rates of the coal-face men showed an even greater diminution of response to temperature in the later statistical period, but the other underground men showed the reverse relationship, as their severity rates responded more to temperature in 1927-28 than they did in 1924-25. Their frequency rates did not differ much in the two periods.
>
> The frequency rate (per 100,000 shifts) and severity rate of accidents in relation to air velocity have been recorded for both statistical periods. In 1927-28 the coal face workers attained a minimum accident frequency of 94 when the air velocity was 40 to 59 ft. per min. and its temperature was 72.2 deg. In air at a velocity of 30 to 39 ft. the frequency was 129, but the temperature was 78.5 deg., and this rise of temperature would increase the accident frequency 7 per cent. Apparently therefore the observed difference of accident frequency could have been due only in small part to a temperature effect, and the same thing is true of the much greater accident frequency observed at velocities of 60 to 80 ft. The other underground men showed, in 1927-28, a much smaller accident frequency

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[74] The Colliery Guardian, Absenteeism in Relation to Atmospheric Conditions: June 5, 1931, pp. 1890-93, 1977.

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at velocities of 150-199 ft. than at either lower or higher velocities, though the 1924-25 data showed a minimum frequency at the lowest velocities. Both statistical periods showed their maximum frequency at the highest velocities, though part of this excess of accidents was due to higher air temperature.

The accident severity rates ran roughly parallel with the frequency rates in both statistical periods, so it may be concluded that both classes of workers showed a genuine increase of accidents at high air velocities. It is probable, though less certain, that they attained their minimum accident frequency at moderate air velocities and suffered an increase of accidents at low velocities. This second conclusion is what we should expect, for it is well known that men engaged on heavy work are more efficient if the cooling power of the air is raised by increasing the degree of air movement. The rise of accidents experienced at higher velocities may be due to the fact that the men often have to wait for periods of several minutes at a time owing to shortage of tubs, etc., and as they are very lightly clad they are apt to get chilled and stiff, and on that account more clumsy and liable to accident. The coal face men usually wear less clothes than the other underground men, and therefore respond to air currents of lower velocity.

The accident rates for the younger men corresponded fairly well with those observed in 1924-25, but the coal face men of 50 and upwards showed an 18 per cent increase in frequency rate, and a 41 per cent increase in severity rate, over the 1924-25 figures. The other underground men of 40 and upwards showed increases of 9 and 30 per cent on the 1924-25 figures. These increases may have been due to the greater fatigue incident to the longer working day. They related especially to the men working at temperatures above 70 deg., and each accident to the older men entailed an absence from work which was, on an average, 22 per cent greater than in 1924-25.

Voluntary absenteeism appeared to be closely associated with the labour turnover at the various collieries, and with the distance the men had to walk underground from pit bottom to working place. It was also related to the distance of the homes of the men from the colliery.

Results of a similar study[75] at Scottish colliers are reported below:

The Health Advisory Committee of the Mines Department decided that a field inquiry should be made at certain selected mines in order to see if any factor or factors might be traced which would account for the divergent sickness rates observed. The present report described the results of such an inquiry.

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[75] The Colliery Guardian, Absenteeism in Coal Mines: Vol. 142, No. 3676, June 12, 1931, pp. 2058-2059.

In all, 190 sets of observations were made, an average of 27 per colliery. Of these observations 137 were made at the coal face and the remaining 53 in the haulage roads. Of the Fifeshire pits, those with low sickness rates (A and B) had lower average temperatures than the others, and their cooling powers were higher than those at collieries C and D. At these two latter collieries the air was more humid than at collieries A and B. In many parts of the traveling roads at collieries C and D the air was quite misty through condensation of moisture. The air velocities shown for collieries D and E are somewhat higher than those at the low sickness collieries A and B, but during the last six years a new fan has been installed at colliery D and the ventilation has been greatly improved generally.

Although the temperatures at the other colliery with a high sickness rate (colliery E) are rather higher than at collieries A and B, the cooling powers are much the same, and it cannot be suggested that the physical qualities of the atmosphere account for any difference in the sickness rates. Colliery E is connected underground with a larger colliery owned by the same company, and is ventilated by the spent air from this other colliery. It seems very doubtful whether this fact is sufficient to account for the higher sickness rate observed, but this is the only respect in which the atmospheric conditions appear to be inferior to those at collieries A and B.

Turning to the two Midlothian collieries, it is seen that, although the cooling powers are much the same, colliery F, with the lower sickness rate, is distinctly better ventilated than colliery G. The air velocity at the coal face at the former pit averaged 227 ft. per min., as compared with an average of 47 ft. at the latter. During the period to which the sickness experience relates the difference would be much more marked, for in the last five years the ventilation of colliery G has been completely reorganized and greatly improved. Previously, this colliery was ventilated by the return air from another colliery, but within the last five years a shaft has been driven from the surface to act as an intake to the various seams: In former years there was much black damp, and when the atmospheric pressure was at all low men frequently had to leave the pit in the dark because their lights had failed. It can confidently be said that at the time of the sickness experience the cooling power of the air would be distinctly lower at colliery G than at colliery F.

While it is not possible to point to any single environmental factor, i.e., an excessively high temperature, as being responsible for the differences between the sickness rates at the various collieries, it does seem possible that these differences may be attributable to the combined operation of the environmental factors discussed. The atmospheric conditions were generally not as good at the collieries with high sickness rates as at those with low rates. Though the differences observed were not great it is possible that prolonged exposure to such inferior conditions, while arduous work is being done, may account to some extent for the higher sickness rates observed. Other conditions also may be partly responsible for the differences between the sickness rates of collieries F and G. The men at colliery F are much the better housed, and live nearer to their work. It has also been mentioned that, while there was a good deal of water along some of the coal faces at colliery G, colliery F was fairly dry, also, the work of coal getting was probably more exacting in the vertical workings of colliery G than in the more moderately inclined workings of colliery F.

Absenteeism of surface workers varied between 1.5 and 5.0 per cent. The investigators are not able to suggest the causes of this variability, but it is interesting to note that at colliery A (a very gassy pit), where the underground workers' absenteeism amounted to 10.6 per cent, the surface workers lost only 1.8 per cent of possible time. The objection to working at a gassy pit does not apply in the case of surface workers, and they probably form a good deal more stable population than the underground workers.

According to Bedford,[76] certain observations on working capacity of coal miners in relation to atmospheric conditions suggested that in a hot, dry mine it might be possible to improve conditions by means of artificial humidification, and an experiment was carried out at a certain colliery. The results showed that where the rate of heat emission was low, the cooling influence of the humidification was felt over a reasonable distance. When the atomizers were situated 120 yards from the coal face the air temperature 85 yards beyond them was still 3° lower than with normal ventilation. However, when the rate of heat emission was high, as along the coal face, the cooling effect of conditioning was soon lost. For instance, although the conditioned air reached the cool face 7.8° cooler than under normal conditions, by the time it had traveled along 35 yards of face this difference was reduced to 1.0°. The experiment was carried out under favorable conditions, in a district with good ventilation. With a more sluggish ventilation the rise in temperature after conditioning would probably have been much more rapid. It was concluded that air conditioning by artificial humidification is not likely to be of value for general application in hot and dry mines. The method might, however, be used in such mines as a palliative measure in certain isolated circumstances, always provided that the humidification could be done quite close to the working position. The real solution of the high-temperature problem appears to be the provision of large volumes of rapidly moving air.

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[76] Bedford, T., and Warner, C. G., The Reduction of Mine Air Temperatures: Colliery Guard., vol. 143, No. 3687, Aug. 28, 1931, pp. 699-700.

An investigation of atmospheric conditions in hot and deep mines is being carried out under the supervision of Graham at the Birmingham University Mining Research Laboratory and also at a number of collieries.[77] The investigation falls naturally into two sections: The examination of atmospheric conditions and methods for their possible improvement, and the determination of the physiological effects of these conditions.

Tests have been carried out both in the laboratory and underground to determine the effect on atmospheric conditions of increasing the velocity of the air current and the most efficient means of attaining an increased velocity. Local circulation by means of a fan and the use of an auxiliary fan as a booster have both been tried, and under the conditions of test the latter arrangement has shown a distinct advantage. Natural ventilation has been studied in a Lancashire colliery and similar observations are to be made in north Staffordshire.

In connection with the examination of the effects of ventilation, observations have been made on airway resistance and leakage. For their more precise measurement, attempts are being made to devise an instrument of increased sensitivity and accuracy.

The physiological researches have included observations of the effect of periods of rest and work in warm and moist air at temperatures lower than normal body temperature. Results on this phase are being prepared for publication.

Bonnardel and Langier[78] summarized work that has been done in an artificial mine 8 meters long and having a cross section of 2½ meters. It contains devices for ventilation (fan delivering 10 cubic meters per second), air heating (gas boiler generating 18,000 calories per hour), humidification (helicoidal fluid jet atomizers) which thus permit of varying the ventilation, the temperature, the hygrometric degree, and of obtaining temperatures of 40° C., in an atmosphere saturated with moisture, with an air velocity reaching 6.40 meters in a gallery 1 meter in height. The essential results are as follows:

(1) Ventilation and Circulation.- The ventilation, with the subject in repose, brings about a reduction in the maximum arterial pressure, particularly at high temperatures; during the work the increase in pressure is diminished by the ventilation.

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[77] The Colliery Guardian, Safety in Mines Research Board Ninth Annual Report: Vol. 143, No. 3689, Sept. 11, 1931, pp. 901-902.

[78] Bonnardel, R., and Langier, H., The Physiology and Psychology of Work: Colliery Guard., vol. 143, No. 3696, Oct. 30, 1931, p. 1502.

(2) Ventilation and Respiration.- (a) When the effect of the wind becomes manifest in symptoms of cold, no matter how slight (goose flesh, etc.) the amplitude of the respiration, the production of CO_2, the consumption of O_2, and also the emission of vapor by the respiration are much higher than in a calm.

(b) Under average conditions in which the effects of the wind or calm on the sensation of warmth are deemed to make no difference, the amplitude of the respiration and of the production of CO_2 are not affected by the wind, but the emission of vapour decreases considerably in the wind.

(c) In cases (high temperatures of over 30°) in which the wind produced an agreeable sensation, the amplitude of the respiration increases under the action of the wind, the production of CO_2 diminishes slightly, and the emission of vapor decreases considerably.

(d) At extremely high temperatures, i.e., air warmer than the body, the amplitudes of respiration and also the production of CO_2 are greater in the wind than in a calm, the emission of vapour being considerably greater in the wind than in a calm.

(3) Study of the Loss of Water.- In repose, the ratio between the water lost by respiration and the water lost through skin (evaporatory quotient of Boussaguet) is about 40 per cent. During work it falls to 12 to 16 per cent. In a dry atmosphere a ventilation of 2 to 3 m. per sec. may cause this quotient to fall below 2 per cent. On the other hand, "any deviation in temperature between the dry thermometer and the wet thermometer of less than 4°, when the wet thermometer is above 24°, indicates a surrounding atmosphere incompatible with the physiological working conditions."

(4) Action on the Thermal Regulation.- The ventilation distinctly assists the thermal regulation.

(5) Effect on the Efficiency.- In comparing the work done with the quantity of CO_2 evolved, Langlois and Routheir conclude "that, in an atmosphere having a temperature adjacent 25° on the wet thermometer, an air stream striking the worker at a velocity of 1 m. per sec. considerably increases his efficiency."

(6) Effect on Pathological Conditions.- Investigations on animals; comparison of working conditions on normal guinea pigs and tuberculous guinea pigs. The hypothermia, which is a function of the hygrometric state, is more pronounced in tuberculous animals than in healthy animals, and the consequences, which are mild in the case of the healthy animal, are serious in the sick animal.

Vernon,[79] who dealt with the influence of the humidity of the air on working capacity at high temperature, recalled the statement by Haldane that the wet-bulb temperature alone has to be considered in measuring the maximum temperature which can be borne by men (e.g., miners) performing mechanical work at high temperatures, and that the dry-bulb temperature can be ignored. On the other hand, Yaglou and his colleagues maintain that the dry-bulb temperature of the air exerts a considerable influence, as well as the wet-bulb, and they have combined the three factors of dry-bulb temperature, wet-bulb temperature, and air velocity into a single measure, which they term the effective temperature. For instance, still air with both wet and dry bulb temperatures at 70° F. would have an effective temperature of 70°, but if the wet bulb was 70° and the dry bulb 100° the effective temperature, according to their charts would be 80.5°, or 10.5° higher. Yaglou accordingly suggests that the air in hot mines ought to be conditioned by increasing its humidity by means of a water spray. In order to obtain further information, two subjects have performed a number of 3-hour experiments in air at a wet-bulb temperature of 70°, 75°, 80°, and 85°, and at a velocity of 93 feet per minute. One subject performed mechanical work roughly corresponding to the work of a coal miner (14,400 kilogram-meters per hour). His pulse rate increased with rise of wet-bulb temperature, but in dry air 40 per cent saturated with moisture the mean pulse rate, at a given wet-bulb temperature, was about six beats per minute higher than in air 60 per cent saturated with moisture and 10 beats higher than in moist air 95 per cent saturated with moisture. On the other hand, the pulse increased steadily as the effective temperature increased, whether the air was dry or moist. The pulse of the other subject, who performed very little mechanical work, also corresponded with the effective temperature scale and not with the wet-bulb temperature. The effects were smaller in summer than in the winter, owing to acclimatization. The body temperature of both subjects rose slightly with rise of effective temperature. The skin temperature, which was taken by means of a Moll thermopile, rose steadily with rise of dry-bulb temperature. The oxygen consumption of the subject was fairly steady at all temperatures, but it reached a minimum at 76° and rose 3 per cent at higher effective temperatures. Both subjects felt considerably more fatigued after remaining for three hours in dry air than in moist air of the same wet-bulb temperature. The subjects made a number of preliminary experiments in order to get themselves acclimatized, but acclimatization effects can never be entirely avoided. For instance, when four consecutive experiments were made in dry air at 100° (dry bulb) and 80° (wet bulb) the mean pulse rate of the subject doing mechanical work fell gradually from 121.2 to 117.2, while the loss of sweat increased from 16.8 to 20.2 ounces per hour. The next three experiments were made in moist air at 81° (dry bulb) and 70° (wet bulb), and the sweat amounted to 17.7, 12.7, and 10.8 ounces, respectively (i.e., it fell gradually as the effect of the preceding dry-air experiments wore off).

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[79] Vernon, H. M., Effect of Humidity on Working Capacity: Colliery Guard., vol. 143, No. 3696, London, Oct. 30, 1931, p. 1502.

France.- The following interesting statement regarding the methods of experimentation used in the United States was published recently in Chaleur & Industrie:[80]

> We have already published, either in the review or in the different volumes devoted to the works of the last Congress on Heating and Ventilation, a certain number of studies on the ideas of effective and equal comfort temperatures to which the Americans have devoted such long and costly researches.
>
> The usefulness of these ideas one will judge by reading the remarkable study that M. Missenard-Quint has just given us on the subject.
>
> And we will add that, in a letter which accompanied his article, our collaborator has given us some very curious details on American methods of working. We do not think that we can do better than to reproduce them here. *****
>
> > The Americans, our collaborator tells us, have dispensed enormous sums in studying the ideas of comfort and effective temperature which they have finally summarized in a graph.
> >
> > All these studies, as almost the totality of American investigations, have been made by pure empiricism, which is a guarantee of their exactitude with good experimenters; but the process can be used only by that nation whose pecuniary resources are almost unlimited. *****
> >
> > Moreover, it ensues from all my technical relations with the Americans that their form of culture does not lead them to theoretical researches, for which they have little taste in general.
> >
> > The following study, which makes use of some of their experiments (the thousandth part, perhaps, of their empirical work), permits by theoretical considerations not only the coordination and explanation of their results but their generalization by increasing the number of variables they propose to make empirically but have not yet realized.

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[80] Missenard, A., Temperature Effective d'un Atmosphere Temperature Resultante d'un Milieu: Chaleur & Ind., vol. 12, No. 137, Sept., 1931, pp. 491-498; No. 138, Oct., 1931, pp. 553-557.

> Some of the American engineers, to whom I have spoken of this work, have been astonished that one can save the millions of dollars spent on their laboratory researches by pure theory based on a rather restricted number of tests.
>
> They have, in fact, insisted that I communicate this work to them to be published in American journals and in particular the Journal of American Society of Heating and Ventilating Engineers. I refused, believing that it should be published first in a French journal, in which, moreover, the readers perhaps could express some interesting objections.

Germany.- Strauss and Walther[81] state that they determined through various experiments that for the present neither the "effective temperature" of the Americans nor Hill's kata degree offers a reliable basis for the comprehension of atmospheric effects on human beings. They summarize the results of their investigations as follows:

> Neither in the body nor in the skin temperature and especially in elimination of water is the influence of (high temperature) moving air prominent in the cooling of the working body. The physiological significance of air movement bears no relation to the alteration of the cooling power of the atmosphere conditioned thereon, as it finds its physical expression in kata degree.
>
> In this connection we would not overlook the fact that the body through movement at work itself creates a light fanning air movement which in our case amounted to 0.3 m./sec. and with the naked body might indeed prevent stagnation of the air in closest proximity to the body.
>
> Everyone who in a hot climate has hunted the pleasantness of moving air will oppose the idea of this slight objective value of the wind. Since ventilation does not result in cooler air, or weaken the action of radiation or, with the body clothed, remove the vapor-saturated atmosphere between the skin and clothing, as is very significant objectively, one must distinguish between objective and subjective effect. Also our subjects - if it did not reach too high a degree (28° and 2 m./sec. air circulation was badly borne) - found the atmosphere agreeable. This influence, however, was very transitory; no one experienced an essential lightening of the work, especially was the feeling of strain after the work entirely the same, and the necessity for relaxation always given in the same measure. Temperature and humidity acted on the capacity for work and the feelings to a far higher degree than did the air movement.

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[81] Strauss, W., and Walther, K., Klima und Arbeit. II. Mitteilung. Der Einfluss ruhender und bewegter warmer Luft auf die Entwärmung des unbekleideten, arbeitenden Menschen: Arch. Gewerbepath. und Gewerbehyg., vol. 1, No. 5, Jan. 15, 1931, pp. 634-655.

The significance of the subjective factor is not undervalued. In industrial processes one must very often grasp the means of alleviating the subjective because one can not do much with the objective; but one should not deceive himself regarding the relatively slight objective value of such measures. We need only to point out that the highest temperature in our experiments did not reach the atmospheric limit for industrial work, that, for example, work is carried out at higher temperatures in mines at home and abroad. Our own experiences in such industries have taught us to see the subjective significance of air movement, as well as the danger which lies in a valuation of the atmosphere somewhat according to the kata degree. The body reacts - as has been emphasized repeatedly - otherwise than the physical instrument. In any case we have found no relation between kata degree and physiological reaction, and therefore we can not resolve to consider the kata value - so long as no other physiological and objective criterion is brought forward for its usefulness - as a measure for the estimation of climatic action on human beings. The special advantage of the kata thermometer, that is, high sensitivity to the fine and finest air streams, is expressed much earlier in the climatic-meteorological study.

Recently the "cooling power" of a climate has aroused the greatest interest as a new, comprehensible conception from the standpoint of industrial hygiene. Under the supposition that this conception is not only meteorologically clear but also physiologically correct, one dares hope to attain in industrial establishments, for example, such as mines, a greater cooling power and thereby greater relief to the workers through increase of ventilation. Our experiments indicate forcibly that such relief is not so simple to bring about and is only to be expected when the indrawn atmosphere, aside from the addition of fresh air, also at the same time lowers the temperature at the working place. Air movement in itself is not of decisive influence on the cooling of the body.

United States.- According to Heating, Piping and Air Conditioning,[82] many accidents and sicknesses may reasonably be ascribed to, and in many instances are definitely proved to be, the result of bad air. Accidents are avoided in many cases by mental alertness, and while the mental effects of poor air conditions are not measurable, we know from the physiological effects that they must be great. A clearer knowledge of the underlying causes of accidents would be desirable. It is not sufficient to locate and measure hazards; more should be known about contributing conditions, such as poor air and poor lighting. There is no doubt that the conditions surrounding employees have a lot to do with accidents; more specific data are needed.

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[82] Heating, Piping and Air Conditioning, Air Conditioning Prevents Accidents: Vol. 3, No. 9, Sept., 1931, p. 807.

During the past two years the Harvard School of Public Health, in cooperation with the Research Laboratory of the American Society of Heating and Ventilating Engineers,[83] has been studying the problem of ionization in relation to air conditioning and health. Several phases of the work dealing with diurnal and seasonal variations in the ionic content of outdoor and indoor air, ionic changes due to respiratory and metabolic processes, and the deionizing effects of air conditioning methods have already been completed. The phases of the work now being studied are:

a. Physiologic, bacteriologic, and biochemical effects of artificially ionized and de-ionized air.
b. Relationship between seasonal variation in atmospheric ionization and seasonal variation in the incidence of respiratory diseases.
c. Methods for artificial ionization of air.

Other plans of the committee for future work include the physiologic, bacteriologic, and biochemical effect of cold and of humidity on human beings and animals.

Very little information is available on the effects of cold upon the organism. The region covered by the Research Laboratory extends from 80° E.T. upward. In the opinion of the committee, the Research Laboratory should complete this work, which, in conjunction with the study on ionization, may throw some light on the etiology of respiratory diseases.

Concerning the influence of humidity on the organism, the committee proposes a thorough study of the effects of changes in humidity through a range of 60 per cent at three different temperatures, namely, 40°, 70°, and 95° F., with the possibility of determining the optimum humidity zone. Observations are to be made on men as well as on animals. The observations on animals are to include the course and resistance to pneumococcus and enteric infections at high and low humidities, growth, reproduction, etc.

Intensive investigations have until now failed to discover the specific cause of deadness, or lack of a stimulating quality, in the air of occupied rooms, even when temperature and humidity are controlled, as contrasted with the air of the open country. Proponents of the open-air treatment ascribe this quality of freshness to a vital principle which is lost when air is brought indoors, particularly when ventilation is effected by mechanical means.

In recent years, since the carbon dioxide, oxygen, and crowd poison theories have become obsolete, ionization has been suggested as the air-soluble vitamin, but it has not yet been identified. The virtues of artificially ionized air have been extolled on purely theoretical grounds, with no scientific confirmation whatever.

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[83] Heating, Piping and Air Conditioning, (Report of Technical Advisory Committee, C. P. Yaglou, Chairman), Air Conditions in Relation to Comfort and Health: Aug., 1931, p. 712.

A series of experiments[84] was carried out on ionization in relation to ventilation and health in occupied and unoccupied rooms with no ventilation, with window-gravity ventilation, and with mechanical ventilation, in order to determine the extent to which the number of small ions is affected by respiration and transpiration, and by modern air-conditioning methods. In contrast with the prevailing belief, the ionic content in unoccupied heated rooms did not differ much from that out of doors, and in cold weather it was often higher, owing probably to a temperature effect. In occupied rooms there was a marked decrease in both positive and negative ions. Immediately after the occupants assembled, the ionic content of the air fell abruptly to a very low value, which was maintained until the occupants left the room. Both positive and negative ions began to rise again as soon as the people departed.

The minimum supply of outdoor air required to maintain normal ionic content in a crowded room was found to be prohibitively high (160 c. f. m. per person). With the usual air supply of 30 c. f. m. per person, the ionic content did not seem to differ greatly from that with no ventilation at all. On the other hand, it was possible by means of artificial ionization to control both the quantity and the quality of ions at any desired concentration up to 10,000 ions per cubic centimeter, with or without ventilation. Mechanical ventilation reduced the ionic content from 0 per cent to 30 per cent by diffusion and adsorption to metal conductors. Heating the air by means of a central fan system increased the ionic content, and cooling by similar methods decreased it. The usual methods of washing, humidifying, or dehumidifying by means of water sprays deprived the air of all small ions and produced a great number of large negative ions, or condensation nuclei, by the well-known Lenard effect. Recirculation reduced both positive and negative ions by diffusion and adsorption to metal conductors.

Houghten[85] and co-workers report the results of 135 heat balance tests made on five subjects in various atmospheric conditions and performing work on a work machine by raising and lowering a weight. Heat quantities were determined by observations of the metabolic rate, and balances were computed by assuming that the total heat dissipated from the body equals the heat production minus the heat storage in the body minus the heat equivalent of the work done on the work machine. This quantity is broken down into sensible and latent heat by assuming that the weight loss is due to evaporation at body temperature. The following is a summary of the results of these tests:

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[84] Yaglou, C. P., Benjamin, L. C., and Choate, S. P., Changes in Ionic Content of Air in Occupied Rooms Ventilated by Natural and by Mechanical Methods: Heating, Piping and Air Conditioning, Oct., 1931, pp. 865-869.

[85] Houghten, F. C., Teague, W. W., Miller, W. E., and Yant, W. P., Heat and Moisture Losses from Men at Work and Application to Air Conditioning Problems: Heating and Ventilating, vol. 28, No. 10, Oct., 1931, pp. 78-79.

1. This report contains data in the form of curves giving the rate of total heat loss, heat loss by radiation and convection, and heat loss by evaporation for men working at three constant rates in still air at various temperatures and two humidities. Corresponding curves for these losses with subjects seated at rest are also given.

2. Data for practical application and examples showing how it may be used in the solution of problems in air conditioning are presented.

3. A table showing the metabolic rate for different kinds of activity is given and the application to practical problems is shown.

4. Total energy production, energy loss, and heat loss are shown to be functions of effective temperature.

5. Sensible and latent heat loss are shown to be functions of dry-bulb temperature and only slightly affected by relative humidity except at extreme temperatures.

6. Sensible heat loss for men working increases but little over this loss for men at rest.

7. Latent heat loss increases rapidly with physical activity and is depended upon almost solely by the body for maintaining a constant body temperature with varying rates of heat production.

8. The comfort zone for men normally clothed and working at 33,075 ft.-lb. per hr. is given at 46° to 64° effective temperature and the comfort line as 53°.

9. The degree of perspiration experienced by men working at 33,075 ft.-lb. per hr. is given for various temperatures and humidities.

According to Humphreys:[86]

Many people who should know better seem to have surprisingly vague, if not even confused, ideas about humidity. Those who have to do with the measurement of humidity would insist, if questioned, that they know perfectly well what the terms "absolute humidity" and "relative humidity" properly mean. Perhaps they do; nevertheless many, if they should condescend to answer at all, would say, in substance, that absolute humidity is the mass of water vapor present per unit volume of the air, and relative humidity the ratio of the amount of water vapor present to the amount necessary to saturate the air at the same temperature.

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[86] Humphreys, W. J., (in Monthly Weather Review, July, 1931) A Common Humidity Error: Heating and Ventilating, vol. 28, No. 11, Nov., 1931, p. 52.

That sounds familiar and orthodox, but it reveals confusion at best, for the air has nothing to do with either absolute humidity, properly defined as the mass of water vapor per unit volume (of space, not air), or relative humidity--the ratio of the mass of water vapor present per unit volume (of space) to that which would saturate a unit volume at the same temperature. Be certain not to add "and same pressure," which we sometimes hear, for that refers to the atmosphere, which, as just stated, has nothing to do with the phenomenon in question.

There is, however, one very useful humidity concept that does involve the air, namely, the mass of water vapor per unit mass of humid air. This is called "specific humidity."

But entirely apart from definitions we often see and hear expressions about the air taking up water vapor and about the great avidity of warm air for water vapor. Now, as a matter of fact, the air does not "take up" water vapor--it is not a sponge; and warm air has no avidity, chemical or other kind, for water vapor. All the air does in this connection is to slow down the rate of evaporation and diffusion. It is not the air but the space, air or no air substantially alike (a shade better without the air), that has the vapor capacity. Neither is it the temperature of the air but the temperature of the vapor (again air or no air) that determines the amount of water vapor per unit volume necessary to produce saturation.

Most of us say the air takes up water vapor. Let us forget it, if we can, and say space instead, as that is what we mean, if we understand the phenomenon aright.

Weeks[87] describes a new instrument, the "coolometer," for measuring the cooling power of the environment. Its essentials are a copper spool covered with a copper shell, the spool being wound with heating coils which constitute also an electrical thermometer operating on the null principle to hold the desired temperature. The current input when the desired temperature is reached gives the rate of cooling, when combined properly with the constants of the instrument. The instrument can be operated as a reflecting or a black body, and thus can be used to study radiation. With the reflecting surface it can be used as an anemometer. Its construction is such that recording devices can be applied. It can be operated dry, or covered with a wet wick.

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[87] - Weeks, W. S., A New Instrument for Measuring Cooling Power. The Coolometer: Jour. Ind. Hygiene, vol. 13, No. 7, Sept., 1931, pp. 261-265.